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ANNUAL PROGRESS REPORT
RANGE REVEGETATION INVESTIGATIONS

FORAGE & RANGE BRANCH
CROPS RESEARCH DIVISION
AGRICULTURAL RESEARCH SERVICE
UNITED STATES DEPARTMENT OF AGRICULTURE

in cooperation with

INTERMOUNTAIN FOREST
AND RANGE EXPERIMENT STATION
and
UTAH AGRICULTURAL EXPERIMENT STATION

by

A. T. BLEAK, RANGE CONSERVATIONIST
EPHRAIM, UTAH

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Intermountain Forest and Range Experiment Station

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Utah State University

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Two copies (1 and 2):
Forage & Range Branch
Crops Research Division
Plant Industry Station
Beltsville, Maryland

One copy (3):
Director
Intermountain Forest & Range Experiment Station
Forest Service, USDA
Ogden, Utah

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Director
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Logan, Utah

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I. INTRODUCTION -- CRc6: PASTURE AND RANGE INVESTIGATIONS UNDER ARID, SEMI-ARID, AND SUB-HUMID CONDITIONS INCLUDING SILAGE AND HAY PRODUCTION

The following report covers the artificial revegetation investigations conducted in central Utah during the period April 1, 1959 to March 31, 1959. This is the fourth progress report that has been submitted since the work in central Utah was reactivated in the late summer of 1956.

Work initiated included laboratory studies on seed germination: behavior of seeds and seedlings under a snow cover during the winter months; factors determining stand establishment from early and late fall plantings; seedling emergence and behavior at selected depths of planting; a study of flooding during rapid snowmelt in the spring; and a study of plant growth and "dormancy" during the fall and winter months. This work has been initiated to further explore the factors influencing the success or failure resulting from revegetation on harsh sites, especially at high elevations.

I-A. Foreign Visitors and Technical Assistance

Approximately 6 hours were spent with a team of 6 Spanish doctorate forestry engineers that were visiting the United States of America to observe rehabilitation and management of depleted range and watershed lands. Four hours were spent with George Tzioumakis and George F. Anagnostou from Greece. In addition 57 hours were spent giving technical assistance and reviewing research findings with extension workers, action agencies and private groups.

I-B. Vehicles at Ephraim, Utah

1. 1954 truck, pickup, ½ T. Ford, V-2593-ARS, License A-57211. Mileage on March 31, 1960 — 49,212 — good condition.

2. 1955 truck, pickup, ½ T. Willys Jeep, V-2593-ARS, License A-57211. Mileage on March 31, 1960 — 31,488 — poor condition.

II. CRc6-2: EVALUATION OF GRASSES AND LEGUMES ALONE AND IN COMBINATION FOR ADAPTATION TO RANGE CONDITIONS

Suitable species are needed to increase forage production, to maintain soil stability and prevent destructive floods. Species should be used which are adapted to the environment. Species may be well adapted to a particular climate or soil but still fail because of some other environmental factors. This had led to an effort to distinguish between those inherent climatic and edaphic factors which must be met by species selection as opposed to factors such as grazing use, insects, rodents, and disease.

II-A. Desert Range Lands of the Intermountain Region

Desert range lands of the Intermountain Region have been seriously depleted. At present there is urgent need to rehabilitate vast areas of these ranges to stop further deterioration by wind and water erosion, to stop deposition of sediment in lakes, reservoirs, and river basins like the Colorado and Virgin, to control noxious weeds, and to increase forage production, especially on winter ranges.

The desert range lands of this region cannot be considered a single homogenous type, similar to the big sagebrush or pinyon-juniper types. These desert lands include two major types when considered from a broad point of view. (1) In the northern shrub type, maximum temperatures above 100°F. are rare and there is usually a cold rest period during the winter and a drought rest period in midsummer. (2) The southern desert shrub type is characterized by high summer maximum temperatures for 5 or 6 months of the year, often above 100°F. Mild winters, and a drought period in both spring and fall are the rule.

II-A-1. Northern Desert Shrub Type

The northern desert shrub type occurs mainly toward the southern and southwestern parts of the Intermountain Region. Big sagebrush is not considered to be a major species in the northern desert shrub type in this report. The largest continuous area extends from the Carson Desert of west central Nevada south and east to the dry mountain region of Death Valley and southern Nevada. This type forms a distinct zone between the sagebrush zone to the north and the southern desert zone to

the south. A second large area lies in the arid portions of western Utah. A third area is located in the Green and Colorado River drainages of eastern Utah and western Colorado. Isolated islands of this type extend northward into eastern Oregon, southern Idaho, and southwestern Wyoming.

In general it can be said that the climate of this zone is distinctly drier than the sagebrush zone. The mean annual precipitation for six desert shrub stations in western Utah averaged 7.95 inches, while that for four sagebrush stations averaged 14.84 inches or again almost twice as much as in the desert shrub type. Dr. D. W. Billings reported mean annual precipitation at all stations in western Nevada and eastern California in the northern desert shrub type, ranged from 3.08 inches to 5.68 inches, with an average of 4.51 inches for the zone. This is about one-half the average mean annual precipitation of 8.79 inches for 6 stations in the sagebrush zone in northern and western Nevada.

Mean January temperatures in the northern desert shrub type appear to be higher than in the sagebrush zone. The summer temperatures of the northern desert shrub type in western Nevada are distinctly higher, about 50°F., than those in the sagebrush zone. The higher summer temperatures in the desert shrub zone are undoubtedly reflected in higher evaporation, resulting when coupled with lower precipitation in greater aridity.

The northern desert shrub type can be conveniently broken down into several distinct communities or associations. These are permanent communities, to some extent determined by soil conditions within the

limits set by climate. The most important or largest communities are listed below in the order in which they frequently occur in going from the big sagebrush type toward the heavier moister soils surrounding a lake or marsh on the valley floor.

1. Black sagebrush (Artemisia nova)
2. Galleta grass (Hilaria jamesi)
3. Little rabbitbrush (Chrysothamnus stenophyllus)
4. Winterfat (Eurotia lanata)
5. Shadscale (Atriplex confertifolia)
6. Greasewood (Sarcobatus vermiculatus)
7. Saltgrass (Distichlis stricta)
8. Pickleweed (Allenrolfea occidentalis)

Due to climatic conditions, returns from the land are low in the desert types, as compared to other range types. Where the native perennial plants have been destroyed, annual grasses and forbs have frequently invaded as shown in figure 1. These annuals produce abundant herbage when climatic conditions are especially favorable, but during drought years plant cover may not be adequate to protect the soil. On some areas, the native perennial vegetation has been replaced by plants poisonous to livestock, such as halogeton (figure 2). From the evidence we have to date, vast areas can and should be rehabilitated through management. However, artificial revegetation is needed and justified on critical areas that need rapid revegetation and on better lands where the returns will offset the cost of operation.

As stated above, average precipitation on the northern desert shrub type ranges from only 3 to 8 inches per year. The precipitation pattern over most of this type has a high winter maximum, with some snow, and a summer minimum. Accumulated winter and early spring moisture is usually adequate for germination of the grass seeds commonly planted in

Figure 1.--Annual species produce abundant herbage when conditions are especially favorable for plant growth (59-120).

Figure 2.--Halogeton has invaded large areas in the northern desert shrub type when the native perennial vegetation has been destroyed (59-98).

this type. Most of the introduced grasses, forbs, and shrubs adapted to this type will germinate at relatively low temperatures. Germination from late fall plantings of crested wheatgrass seed and other seeded species has been observed and recorded from early December through May, depending on soil moisture, soil temperature or both. However, the seedlings perish unless spring and summer moisture conditions are favorable for seedling establishment. Since the seedlings frequently germinate during the winter and early spring, mortality due to frost and freezing has been high.

In the pickleweed, saltgrass, and greasewood associations, physiological drought may be more of a problem than soil moisture. At this time, successful plantings can be made in the saltgrass and in some greasewood types. Experience has shown that these plants must be eradicated for successful artificial revegetation. Greasewood can be eliminated by wheatland plowing or similar methods. Saltgrass is more difficult to eradicate. The method which has given best results is to turn the sod completely under. This can best be done by moldboard plowing to a depth of 4 to 5 inches in the summer or fall when the soil surface is dry. Spring planting has been best on wet alkali lands and late fall or early spring planting is superior on dry alkali soils. Planting procedures which place the seed in a shallow furrow or depression have given better results than drilling directly into the soil surface.

Species adapted to wet alkali areas with a high water table are tall wheatgrass, alta fescue, yellow sweetclover, fivehook bassia and Belvedere summercypress. Promising species, on areas with a low water

table which dries out in summer, are Russian wildrye and crested wheatgrass. On some of these areas, drought tolerance is more important than a tolerance to soil salts.

In the black sagebrush, galleta, winterfat, and shadscale associations, physical drought is the principal limiting factor. Plant growth is restricted by available moisture in the soil as a result of precipitation and soil characteristics. Drought tolerance is generally more important than tolerance to high concentrations of soil salts.

Infrequent severe droughts may restrict seed germination. For example, during a severe drought in western Nevada from July 1954 to September 1955, only 1.47 inches of precipitation fell during this 13 month period. Seeds of planted grasses and shrubs, as well as native annuals and perennials, layed in the soil during the winter, spring, and summer without germinating. Seeds of four planted grasses, (Agropyron cristatum, A. desertorum, A. intermedium, and Elymus junceus) were removed from this area in August 1955 after more than 8 months in the soil. These seeds were not visibly damaged and average percent germination in the laboratory was 80.9 percent while average germination of these same seed lots from stock supplies was 89.2 percent. Field germination from planted seeds of many of the grasses, all forbs, and two shrubs as well as many "native" annuals took place in late September 1955 soon after 1.42 inches of rain fell on this area. Some germination was noted for Agropyron cristatum, A. desertorum, A. intermedium, A. sibiricum, A. trichophorum, Bromus breviaristatus, Elymus junceus,

Sitanion hystrix, Kochia indica, K. scoparia, Erodium cicutarium, and Atriplex canescens. Seeds that did not germinate were Agropyron inerme, Elymus triticoides, Oryzopsis hymenoides, Stipa viridula and most of the shrub species native to this type (Artemisia spinescens, Atriplex confertifolia, A. gardneri, Eurotia lanata, Grayia spinosa, and Sarcobatus baileyi).

Revegetation studies, in the northern desert shrub types of Utah and Nevada, have shown that good seedling stands can usually be obtained from late fall planting with intermediate wheatgrass, tall wheatgrass, crested wheatgrass, Russian wildrye, and many other species. Most of the seedlings perished during the first summer. Desert wheatgrass and Russian wildrye appear to be the best adapted of the introduced grasses, but even established stands of these grasses have usually perished during drought years.

Various methods of planting have been tried. Methods which conserved moisture or provided for collection of additional moisture around the seed and plants have been most successful. This has usually been done by pitting or by making furrows which collect and hold supplemental water (figure 3).

Good stands have been made on desert lands at several locations in Utah and Nevada. One of the most promising plantings was made by Mr. Victor Murray at Cisco, Utah in the spring of 1938. This planting was on clay soils derived from mancos shale and supporting shadscale type of vegetation. Eighteen acres of crested wheatgrass were planted, with a Planet Jr., in furrows that had previously been made with an

Figure 3.--Good stands of crested wheatgrass and Russian wildrye were obtained by broadcasting seed on plow furrows in the fall of 1950. Plantings in shallow furrows and direct planting with a grain drill failed to produce stands (59-88).

alfalfa marker. In 1952, most of the plants still appeared thrifty and there was a moderate number of young plants and seedlings. The herbage production was reduced in 1953. By 1955, the plants were mostly dead, due to light use by horses and the drought in 1954. On July 10, 1955, only rows of dead grass, which had been heaved out during the winter of 1954 and early spring of 1955, could be seen. Remnants of these heaved plants could still be seen in the summer of 1958 (figure 4).

Four acres in Wah Wah Valley, west of Milford, Utah, were planted to mixtures of species in the fall of 1939 and replanted on November 25, 1940 after the 1939 planting failed. A mixture of Agropyron cristatum, A. spicatum, A. smithi, Arrhenatherum elatius, Elymus simplex, and Poa bulbosa were sown on a third of this area. The shrubs, Atriplex canescens, A. nuttalli, and Eurotia lanata were sown on a third of this area and a mixture of grasses and shrubs were sown on a third of the seeded area. The area planted was vegetated with a fair stand of Eurotia lanata and small patches of Hilaria jamesii, which were not disturbed prior to planting. No shrub seedlings from the 1939 or 1940 plantings were found. Crested wheatgrass did well and began to invade the adjoining plots planted to shrubs. Many of the crested wheatgrass plants in the original drill rows are now dead but good seedling stands have been produced by natural revegetation when conditions were favorable (figures 5 and 6). Forage yields are similar where the crested wheatgrass grows in mixture with native winterfat and where the winterfat grows in nearly pure stands. Where the crested wheatgrass and winterfat grow together, both show the effects of competition.

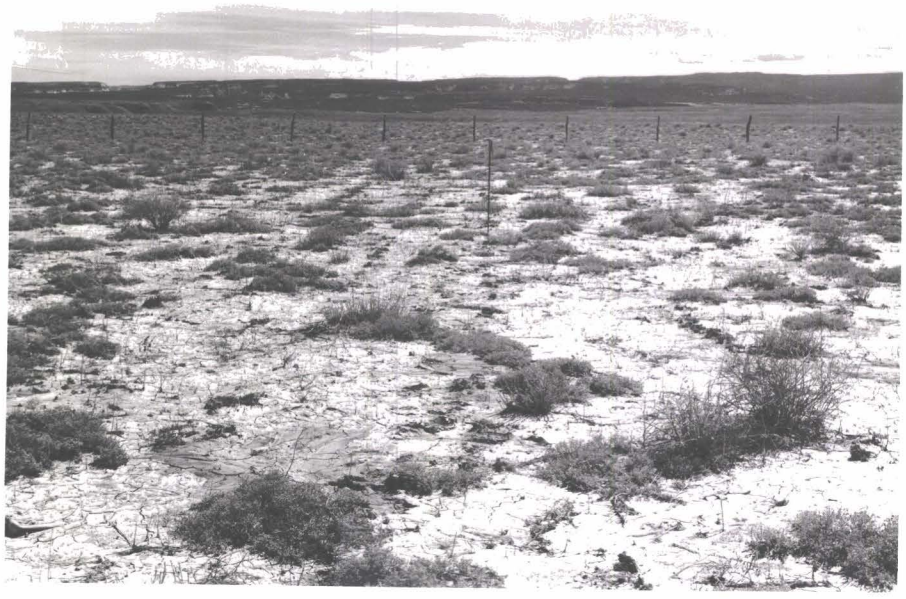


Figure 4.—Dead crested wheatgrass plants can be seen along the old drill rows that were planted in the spring of 1938. This stand persisted until 1954 (59-89).

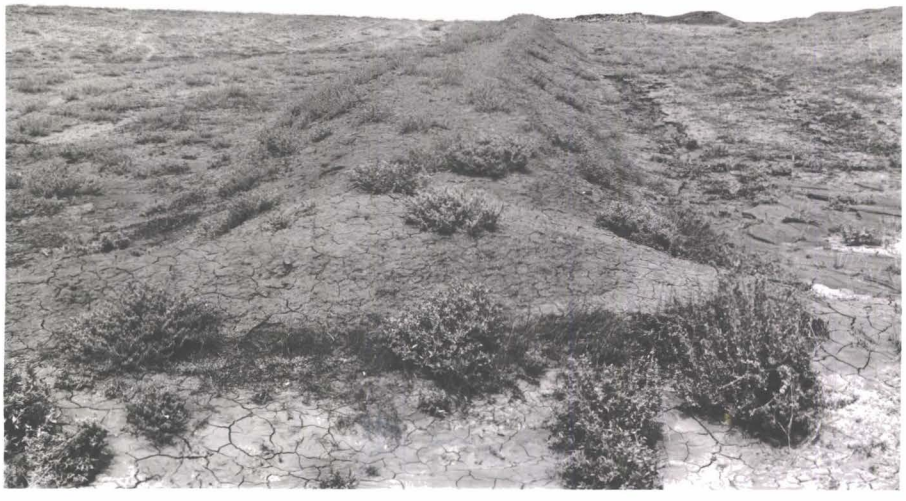
Figures 5 and 6.--Many of the crested wheatgrass plants in the original drill rows planted in 1940 are now dead but stands have been maintained by natural revegetation (59-145 and 59-146).

Four plantings involving 82 species and strains were made within the Colorado River Drainage in the fall of 1950. Despite a dry spring in 1951, seedling stands of one lot of squirreltail, Amur wheatgrass, intermediate wheatgrass, pubescent wheatgrass, crested wheatgrass, and Russian wildrye produced fair to good stands on all sites. In the spring of 1952 there had been some mortality on most species. By 1955 only an occasional plant of crested wheatgrass could be found; and, as shown in figure 7, only the plot stakes and native Atriplex remained by 1959.

Plantings of crested wheatgrass were also made over a gasline running approximately parallel to Highway 6 and 50 near Cisco, Utah. Most of the crested wheatgrass plants are now dead except where supplemental water is available in depressions, swales, furrows, and etc. Native Atriplex had invaded part of the area cleared to put in this gasline as shown in figures 8 and 9.

Successful range plot plantings of crested wheatgrass and Russian wildrye have been made near Gunnison, Utah in the shadscale type in several different years. The stands shown in figures 10 and 11 were planted on November 16, 1950. Species planted at this time included 28 seed sources of crested wheatgrass, including Agropyron desertorum, A. cristatum, and A. sibericum, 24 seed sources of bluebunch wheatgrass, 23 seed sources of Indian ricegrass, 12 seed sources of Sitanion hystrix, and 11 seed sources of Atriplex canescens. Good seedling stands were produced by most of the crested wheatgrass sources, fair seedling stands were produced by most sources of bluebunch wheatgrass, fair stands were produced by most sources of Indian ricegrass,

Figure 7.--Fifty-six species were planted on this area in the fall of 1950. Some species produced fair initial stands but all planted species were dead by 1959 (59-86).



Figures 8 and 9.--This area cleared to put in a gasline near Cisco, Utah was planted to crested wheatgrass. Most of the crested wheatgrass plants are now dead but native Atriplex has become established on some sections (59-91 and 59-95).

Figures 10 and 11.--A few sources of crested wheatgrass planted in the fall of 1950 have maintained good stands. As shown in the lower photo some plants have died on most of the plots (59-111 and 59-112).

fair to good stands were produced by most sources of Sitanion and fair to poor stands were produced by the Atriplex sources. By August 25, 1959, some sources of crested wheatgrass had maintained good stands but most stands were only fair. Stands of other species had declined and only a few plants of Atriplex canescens, bluebunch wheatgrass, or native plants could be found. Stands of the natives Sitanion hystrix and Indian ricegrass had usually deteriorated, but a few sources of each still maintained fair stands.

During drought years even crested wheatgrass and Russian wildrye, which have shown the most promise of the introduced species in this type, as well as native Indian ricegrass and Sitanion have perished. In the late fall of 1946 a planting containing 11 grasses was made in the upper shadscale type in Paradise Valley, Nevada. Stands of all species, except crested wheatgrass and Russian wildrye, gradually declined and completely died out in the 1954 drought. The crested wheatgrass and Russian wildrye maintained good stands until the 1954 drought, when 90 percent of the plants were dead and the 10 percent remaining had only 1 or 2 culms within the original plant which were living.

Near Fernly, Nevada, during the 1954-1955 drought, 96 percent of a stand of native Oryzopsis hymenoides plants with an original stand of .7 plant per square foot perished. The surviving plants had only 1 or 2 living culms within the original plant. However, by midsummer in 1956, 0.49 seedling Indian ricegrass plants per square foot were found on this area from seed that had laid over in the soil. Native

shrubs such as Atriplex canescens, A. gardneri, A. confertifolia, Eurotia lanata, and Artemisia spinescens have withstood the frequent droughts much better than most native and introduced grasses. Good stands of these shrubs have been very difficult to obtain for several reasons. Probably most important is the low viability and dormancy of shrub seeds, but rodent damage to seeds and seedlings and frost damage to seedlings have also caused many failures.

There are many factors contributing to the low herbage production and depleted conditions frequently found in the northern desert shrub type in addition to overgrazing and poor management of livestock. Low precipitation coupled with high evaporation are contributing factors which prevail throughout this zone. High salt content or loose, sandy, gravelly, soils with a low water holding capacity are very common. It is evident that insects and rodents are a substantial factor for the low herbage production and poor results obtained from management practices or revegetation projects. Grasshopper and cricket populations ravage the areas in some years. Ants harvest seeds and plants but in addition may occupy large areas as shown in figure 12. Rabbits and kangaroo rats are largely responsible for poor results obtained with seeded species, particularly with the cool season species which produce green growth in the early spring and in the fall when most other vegetation is dormant. As shown in figures 1, 2, and 3, even pocket gophers damage native and seeded stands in this type.

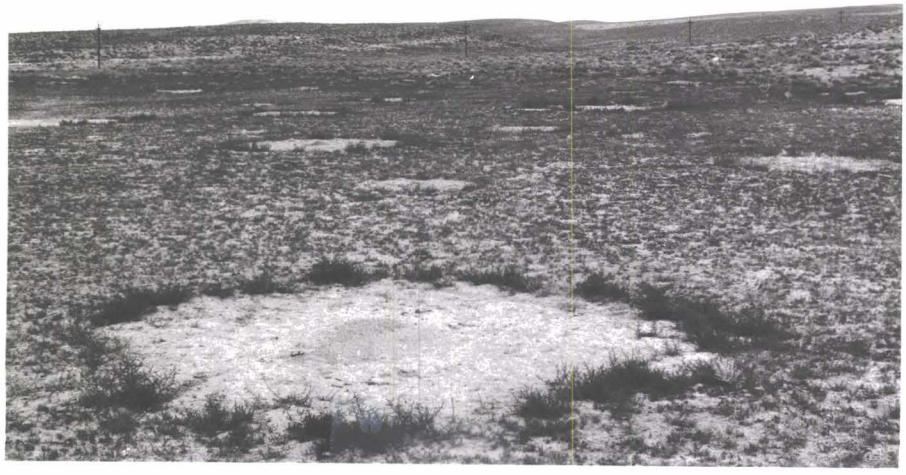


Figure 12.--Ant hills are frequently found in the northern desert shrub types. As many as 26 ant colonies per acre have been recorded in the shadscale type (59-108).

II-A-2. Southern desert shrub type

The southern desert shrub type begins near the Hurricane fault in southern Utah and runs westward into Nevada and crosses into California, south of Goldfield, Nevada. Most of the precipitation in this type is of winter origin with infrequent cyclonic summer storms. This area coincides with the red desert soils. To better delineate the problems in range management and artificial revegetation, the southern desert shrub type has been broken down in two vegetative types.

a. Blackbrush (Coleogyne ramosissima), type or association lies in a broad overlapping belt between the northern and true southern desert shrub type. It is accompanied by both northern and southern desert plants.

Plants commonly found associated with blackbrush are spiny hopsage (Grayia spinosa), Joshua tree (Yucca brevifolia), bursage (Franseria dumosa), Indian ricegrass, scattered areas of galleta grass, annual brome and other annuals. As a rule this association occupies light pervious land. Soils are usually sandy, rocky, or gravelly with a definite erosion pavement in the open spaces between the shrubs and with an accumulation of fine soils under the shrubs. These lands are free from harmful amounts of salts or alkali. Precipitation is between 5 to 10 inches annually with high summer temperatures and high evaporation.

In general the carrying capacity of this type is low. However, the scanty leafage of blackbrush is persistent and available throughout the year. It is reported to provide fair forage for cattle, sheep, goats, and game during the winter. Blackbrush furnishes little forage in the spring or fall.

Many of the blackbrush stands are closed to the interstitial production of annuals. During the past 15 years, several large areas of blackbrush have burned. Removal of blackbrush, cactus, and other shrubs by burning results in increased forage production, especially the annual bromes, alfileria, and other broadleaved herbs. It has also been noted that (Gutierrezia) increases with each additional fire, and will undoubtedly be a problem in attempts to artificially seed these areas.

b. Creosotebush (Larrea tridentata) and bursage (Franseria dumosa) dominate the true southern shrub type located in southern Utah and southern Nevada usually below 3,500 feet elevation. Soils are usually pervious and covered with a prominent desert pavement. Annual precipitation ranges from 3 to 8 inches per year. The dominant shrubs are usually widely spaced. When winter precipitation has been adequate, carpets of flowering annuals cover the ground between and under the shrubs in the early spring months. By May these annuals have disappeared. If an area in this zone receives precipitation from one of the late cyclonic summer storms, there usually will appear another but different aggregation of blooming annuals. Due to the irregularity of these local storms, a given area may not be subjected to such a storm more than once in several years.

Very few live streams cross this type and those that do originate at higher elevations. There is little or no surplus water in any season and the desert pavement does a fair job of controlling normal wind and water erosion. However, local floods from torrential cyclonic storms are not uncommon and active sand dunes are common in some areas.

This type is of restricted importance to the livestock industry due to limited and uncertain production of forage. Grazing of domestic stock is further curtailed by lack of drinking water. A few areas need revegetating to control siltation of streams and reservoirs and to control wind and water erosion. The limited and irregular precipitation, plus high temperatures and high evaporation, increase the problem and difficulties of successful artificial revegetation.

III. CRc6-3: ESTABLISHMENT PRACTICES FOR REVEGETATION OF RANGE AREAS IN THE WEST

Suitable establishment practices are necessary for consistently successful and effective revegetation of depleted ranges on which the present plant cover is not adequate for soil protection or is of low forage values. The upper Colorado River Basin development provides for rehabilitation of this rangeland. This expanding reseeding program is moving work into the extremes of climate and soils on which little is known about reseeding. This magnifies the importance of "know-how" in restoring the vegetation cover. Low precipitation, dry summers, sandy soil, acid soil, steep slopes and rough terrain are some of the factors which require special consideration.

III-A. Seed Germination and Plant Growth Under Natural Conditions

III-A-1. Depth of planting at three sites

Seeds of four species from the 1958 crop were planted at seven depths at three locations on October 20, 1958. Sites were located in Ephraim Canyon at elevations of 5,500 feet (Sorenson's Field), 7,000 feet (Majors Flat), and 8,850 feet (Headquarters Station).

Species used were: intermediate wheatgrass grown on the Frischknecht Farm in Sanpete County, progeny of P2327; a field collection of smooth brome grown at Headquarters Station; native slender wheatgrass from an elevation of 9,400 feet in Ephraim Canyon; and native mountain brome from an elevation of 10,000 feet in Ephraim Canyon. Seed of all species was harvested by hand and thoroughly cleaned to remove all empty glumes and other trash. Seed was separated into units with 100 seeds of a single species per unit. Each unit was placed in a small packet or bag made from nylon netting. Openings in the bags were then closed and stitched to prevent seed loss.

This study was established to provide information on ability of seed to germinate, depth of emergence of shoots, and seed dormancy at various depths below the soil surface. Seeds in bags were planted at the following depths, 1/3 inch (1 cm.), 3/4 inch (2 cm.), 2 inches, 4 inches, 6 inches, 1 foot, and 2 feet, with each species replicated 3 times at each depth. Bags were removed from each area just as the soil was beginning to dry in the spring of 1959.

Seeds were removed from the 5,500 foot site on May 1, 1959. The soil was still moist to a depth of over 2 feet. As shown in table 1, all species had started to germinate at all depths. Many of the seeds were infected with a "prong" fungi, but the fungi will be discussed separately in Section III-A-3. Some seedlings from the 4 inch depth had reached the soil surface but no seedlings from the 6 inch and deeper depths had reached the soil surface. It is believed that additional germination may have taken place if the 1 foot and 2 feet depths had been sampled 10 days or 2 weeks later in the season. Although the nylon sacks worked very well, considerable difficulty was encountered in removing the shoots from the surrounding soil without breaking or damaging them.

Seeds were removed from 1/3 inch to 6 inch depths at the 7,000 foot site on May 13. On this date, soil at the 1/3 inch was quite dry but soil at the other depths was moist. The seeds at the 1 foot and 2 feet depths were removed on June 9.

Seeds at the 8,850 foot site were removed from 1/3 to 4 inch depths on June 24, and seeds from 6 to 2 feet depths were removed on July 6. Soil was quite dry to a depth of 2 inches on June 24 and was beginning to dry to a depth of 6 inches on July 6. On July 6 many earthworms were found at a depth from 9 inches to about 20 inches. The percent of seeds that had started to germinate prior to the time they were removed from the soil varied with species, site (elevation), and with depth. Variation in the depth of planting was much less than expected due to the rather high germination of intermediate wheatgrass, slender wheatgrass and mountain brome seed at the 1 and 2 foot depths as shown

Table [1] .—Percent of seeds germinating when removed from the soil and after 30 additional days in the laboratory that had been planted at three elevations on October 20, 1958 at various depths and removed just as the soil was drying in the spring of 1959

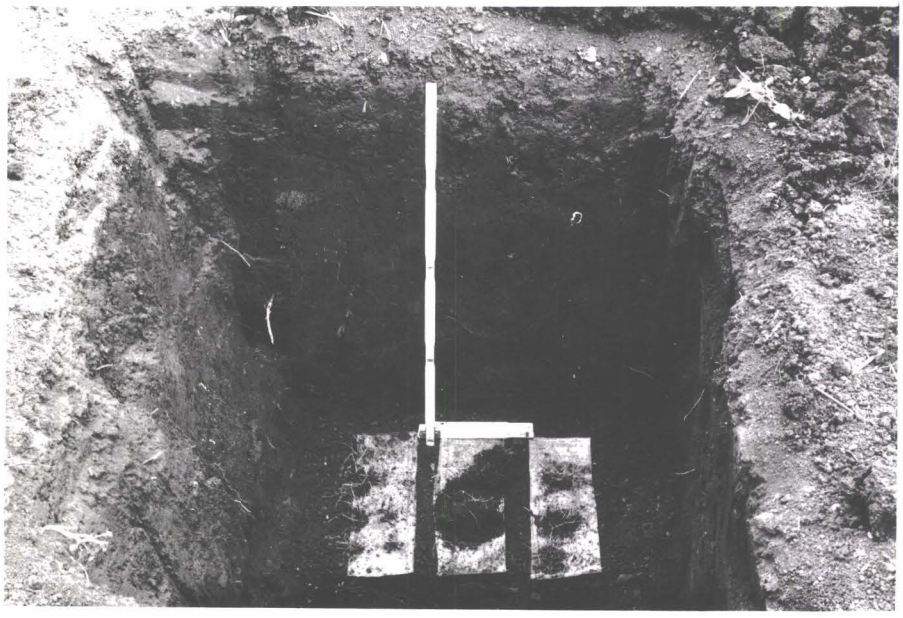
Depth		Intermediate wheatgrass			Slender wheatgrass			Mountain brome			Smooth brome		
		5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/	5,500 1/	7,000 2/	8,850 3/
		Percent											
1/3 inch	Removed	47.7	87.3	83.3	12.0	93.0	89.7	5.7	84.3	3.7	7.3	72.3	70.0
	Complete	53.0	87.3	83.3	15.3	93.3	89.7	14.0	84.7	4.7	30.0	73.3	71.3
3/4 inch	Removed	91.0	83.0	84.7	60.0	86.0	86.3	80.7	91.7	18.7	17.7	46.0	60.3
	Complete	91.0	83.0	84.7	62.7	86.0	86.3	81.0	91.7	24.3	17.7	46.0	80.0
2 inches	Removed	94.7	98.0	94.7	89.0	97.3	95.7	67.3	87.7	40.3	86.3	85.0	78.3
	Complete	94.7	98.0	94.7	89.0	97.3	95.7	67.3	87.7	40.3	87.0	87.0	78.3
4 inches	Removed	95.3	97.3	93.3	76.3	97.7	96.3	68.0	78.7	19.0	82.0	80.7	60.3
	Complete	95.7	97.3	93.3	76.3	97.7	96.3	68.0	79.0	19.3	90.7	83.7	60.3
6 inches	Removed	94.7	98.3	84.3	35.7	97.0	92.0	37.7	84.3	25.7	40.7	58.7	52.0
	Complete	95.3	98.3	84.3	37.0	97.0	92.0	37.7	84.3	28.3	86.0	81.0	53.3
1 foot	Removed	95.3	96.0	91.7	54.7	92.0	97.7	22.3	91.0	27.3	25.7	59.3	58.0
	Complete	95.3	96.0	91.7	55.0	92.0	97.7	22.3	91.0	30.0	72.7	78.3	70.3
2 feet	Removed	85.0	77.7	95.0	19.7	79.3	98.0	95.3	96.3	76.3	6.0	58.0	24.7
	Complete	86.3	77.7	95.0	29.3	81.3	98.0	95.3	96.3	76.7	54.7	71.0	77.0

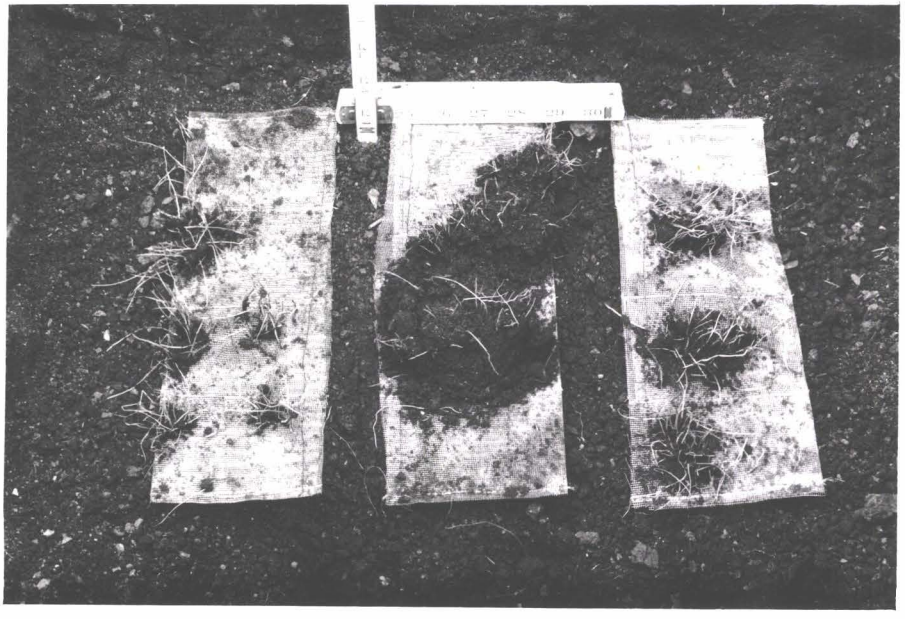
1/ Seed removed on May 1, 1959. Considerable fungi at some depths.
2/ Seed removed on May 13, 1959 except for 1 and 2 foot depths which were removed on June 9.
3/ Seeds removed on June 24, 1959 except that 1 and 2 foot depths which were removed on July 6.

in table 1 and figures 13 and 14. A large portion of the variation between sites and between planting depths appears to be due to soil temperature and soil moisture at various depths at each location. For example, the deep soil at the 8,850 foot elevation was frozen and relatively dry for about 4 weeks after the surface soil had thawed. At the intermediate elevation, the deeper soil was relatively dry until the soil at a depth of approximately 6 inches thawed, allowing moisture percolation to deeper depths although the surface soil had been thawed for some time. No seedlings reached the soil surface from 6 inch planting depth, (table 2).

Maximum shoot penetration found when the seeds were dug from 6 inches, 1 foot, and 2 foot depths was 120 mm., almost 5 inches, for mountain brome seedlings but some intermediate wheatgrass and slender wheatgrass seedlings penetrated 105 mm. upward through the soil.

Seed germination and penetration of seedlings may have been modified to some degree at the lower elevation and to a slight degree at the 7,000 elevation due to fungi attacking the seed. No damage to seed by fungi was observed at the 8,850 foot site.





Figures 13 and 14.--Seeds planted at a depth of 2 feet had germinated when they were removed from the 8,850 foot site on July 7, 1959 (59-68 and 59-70).

Table 2.--Maximum length of shoots produced in millimeters on seeds of four species, planted in the fall when removed from various depths at three sites in the spring of 1959

	Intermediate wheatgrass			Slender wheatgrass			Mountain brome			Smooth brome		
	5,500	7,000	8,850	5,500	7,000	8,850	5,500	7,000	8,850	5,500	7,000	8,850
Depth	Height - Millimeters 1/											
1/3 inch	45	120	106	37	140	130	40	110	45	35	85	83
3/4 inch	98	150	130	76	180	110	50	160	120	35	110	45
2 inches	105	120	108	85	50	110	90	100	80	80	60	85
4 inches	70	70	105	50	90	102	60	100	61	61	70	78
6 inches	75	105	35	55	105	30	50	120	40	60	70	30
1 foot	45	40	35	45	55	30	30	55	40	38	45	30
2 feet	35	20	105	32	78	80	31	73	95	12	35	90

1/ Underlined figures did not emerge from the soil surface

III-A-2. Date of planting in the fall at three locations

Seed of four species from the 1958 crop were planted on four dates at three locations in the fall of 1958. Sites were located in Ephraim Canyon at elevations of 5,500 feet (Sorenson's Field), 7,000 feet (Majors Flat), and 8,850 feet (Headquarters Station).

This study was established to determine when seeds of the selected species germinate in the fall and winter and to evaluate the advantages and disadvantages of early and late fall seedings. Seed lots used in this study, all grown in 1958, were identical to those used in the adjoining depth of planting studies discussed in Section III-A-1.

Seeds in nylon mesh bags with 100 seeds of a single species per unit were planted at all sites on each of the following planting dates: September 17, October 3, October 20, and November 19. On each planting date seeds were placed under 3/4 inch of soil at three separate areas at each site. Three replications of all species were placed at each area except that one additional sampling unit was placed at each site on the first planting date, September 17. The additional sample planted at each site on September was removed from each area and examined for germination 5 days after the last planting was made on October 19 to determine fall germination. Seeds planted on each of the four planting dates were removed from each of the three sites on three dates in the spring according to plant development at that site: (A) early (February 19, and March 2, respectively); (B) during expected period of rapid germination and growth at each elevation (March 26, April 6, and May 26,

respectively); and (C) the final removal was made just as the soil was drying in the spring at that site (May 1, May 13, and June 24, respectively) (figures 15, 16, and 17).

As shown in table 3, the seeds of the four grasses planted on the first planting date, September 17, and removed shortly after the last planting date, November 24, had not started to germinate during this fall period. In general, differences in date of planting on seed germination in the fall and early winter 1958-1959 were much less than anticipated due to a dry, cold fall that prevented or delayed seed germination at all locations due to lack of moisture, low temperatures, or both.

On the second sampling date, February 19, at 5,500 feet, only the introduced grasses, smooth brome and intermediate wheatgrass, had started to germinate. On this date all four species had started to germinate at the 7,000 foot site due to the relatively favorable conditions that prevailed under the existing snow cover. At the upper site, the soil under a deep snow cover was still frozen on March 2; and only intermediate wheatgrass planted on the early planting date had started to germinate. By the third sampling date, seed of all species were germinating rapidly although seed dormancy in the native mountain brome had not been fully broken. Reduced germination at the 5,500 elevation, especially with smooth brome, was caused by heavy fungi infection. Percent of seeds infected with fungi was noticeably higher on the seed planted in the first planting date, September 17, than on the last planting date, November 19.

Figures 15 and 16.--Date of planting studies at the intermediate elevation on May 13, 1959, just before the nylon bags were removed from the soil (59-1 and 59-2).

Figure 17.--Seedlings of mountain brome, intermediate wheatgrass, smooth brome, and slender wheatgrass can be seen protruding through the nylon mesh bags on May 13, 1959 from the seeds planted, on the first planting date, September 17, 1958 (59-13).

Table 3 .--Percent germination from four dates of planting when seeds were removed in late fall (11/24) and at three dates in the winter or spring depending on climatic conditions at each site and after subsequent laboratory germination for 35 days

	Sorenson's - 5,500 ft.				Majors - 7,000 ft.				Headquarters - 8,850 ft.			
	Removal Date											
Pltg. Date	1st 11/24	2nd 2/19	3rd 3/26	4th 5/1	1st 11/24	2nd 2/19	3rd 4/6	4th 5/13	1st 11/24	2nd 3/2	3rd 5/26	4th 6/24
Intermediate wheatgrass - when removed from field												
9/17	0.0	24.3	80.3	68.7	0.0	72.0	89.3	93.0	0.0	3.0	93.7	88.7
10/3	-	15.0	65.7	80.2	-	47.3	70.0	73.3	-	0.0	95.7	89.3
10/20	-	24.3	73.3	91.0	-	69.3	89.7	83.0	-	0.0	93.3	84.7
11/19	-	15.3	87.3	87.7	-	15.7	86.7	92.0	-	0.0	95.0	92.3
	- after 35 days in laboratory											
9/17	97.3	81.7	81.0	68.7	96.7	93.7	90.3	93.0	95.0	93.0	94.7	88.9
10/3	-	90.3	70.0	80.7	-	86.3	70.7	73.3	-	90.0	96.3	89.3
10/20	-	81.7	73.7	91.8	-	91.3	90.3	83.0	-	91.7	94.0	84.3
11/19	-	86.7	91.0	89.3	-	93.0	89.7	92.7	-	95.7	96.0	92.3
Slender wheatgrass - when removed from field												
9/17	0.0	0.0	39.3	44.3	0.0	36.3	91.7	93.7	0.0	0.0	98.0	96.7
10/3	-	0.0	32.0	42.0	-	14.0	90.0	83.7	-	0.0	93.0	90.0
10/20	-	0.0	42.0	60.0	-	14.3	93.0	86.0	-	0.0	95.7	86.3
11/19	-	0.0	15.0	17.0	-	0.3	85.3	81.3	-	0.0	94.0	92.7
	- after 35 days in laboratory											
9/17	48.0	16.0	43.7	49.3	45.3	71.7	93.7	93.7	58.0	35.7	98.0	96.7
10/3	-	21.0	43.7	46.3	-	50.7	90.7	83.7	-	32.7	94.0	90.0
10/20	-	20.7	59.3	62.7	-	68.3	93.7	86.0	-	45.3	96.0	86.3
11/19	-	19.0	28.7	21.7	-	31.7	89.0	81.7	-	47.3	94.7	92.7
Mountain brome - when removed from field												
9/17	0.0	0.0	67.7	62.0	0.0	93.0	93.3	96.7	0.0	0.0	15.3	52.7
10/3	-	0.0	59.3	64.3	-	68.0	88.7	95.3	-	00.0	45.7	30.0
10/20	-	0.0	76.7	80.7	-	81.3	94.0	91.7	-	0.0	23.3	18.7
11/19	-	0.0	63.0	58.3	-	0.7	60.7	66.0	-	0.0	31.7	23.0
	- after 35 days in laboratory											
9/17	42.0	32.0	79.3	65.3	10.3	93.0	93.7	96.7	4.7	1.0	17.0	53.3
10/3	-	25.3	70.7	69.7	-	78.3	92.3	95.3	-	0.7	46.3	32.3
10/20	-	41.7	84.3	81.0	-	90.0	95.3	91.7	-	6.7	25.3	24.3
11/19	-	28.3	70.7	63.3	-	8.0	73.3	68.3	-	11.7	33.0	23.0
Smooth brome - when removed from field												
9/17	0.0	7.0	44.0	19.3	0.0	59.3	63.0	76.3	0.0	0.0	89.7	86.7
10/3	-	4.7	10.7	17.3	-	8.3	13.0	45.3	-	0.0	79.0	66.7
10/20	-	4.3	18.3	17.7	-	10.3	45.0	46.0	-	0.0	77.3	60.3
11/19	-	5.0	62.7	55.0	-	1.0	58.7	88.3	-	0.0	83.3	85.0
	- after 35 days in laboratory											
9/17	91.3	29.0	46.0	19.7	94.3	83.3	65.3	76.3	91.3	90.0	91.0	86.7
10/3	-	46.0	11.3	17.3	-	75.7	14.3	45.3	-	90.3	81.0	66.7
10/20	-	40.7	19.7	17.7	-	66.7	46.7	46.0	-	84.7	79.0	80.0
11/19	-	52.3	70.3	56.3	-	83.3	82.7	89.0	-	91.0	84.0	85.0

The native species (slender wheatgrass and mountain brome) responded somewhat differently from the intermediate wheatgrass and smooth brome seeds as conditions necessary to overcome seed dormancy had to be met before seed germination took place. Intermediate wheatgrass and smooth brome seeds germinated as soon as conditions were favorable.

III-A-3. Fungi on seeds of four grasses

Information on degree of infection by a fungus on intermediate wheatgrass, slender wheatgrass, mountain brome, and smooth brome at three locations (elevations) was obtained as an unexpected bonus from the "Depth of Planting" studies and "Date of Planting" studies. This fungus was in an imperfect stage, and identification has not been made at this time (figure 18).

Seeds of the four grasses were placed in small nylon bags with 100 seeds of a single species per bag at 3 elevations in Ephraim Canyon: 5,500 feet, 7,000 feet, and 8,850 feet. In the "Date of Planting" studies, seeds were buried under 3/4 inch of soil on September 17, October 3, Obtober 20, and November 19. In the "Depth of Planting" studies seeds were buried at 7 depths ranging from 1/3 inch to 2 feet on October 20.

"Date of Planting" samples were removed from the 5,500 foot elevation on February 23, March 26, and May 1, 1959. Fungi was observed on all samples. Accurate counts on seeds infected when removed from the soil and after subsequent laboratory germination were made only on the last sample removed. Number of seeds infected was greatest on early planted seeds and least on seed from the last planting date. "Date of Planting" samples from the 7,000 foot elevation were removed on February 19, April 6, and May 13. A few seeds infected with fungi were found at the 1/3 and 3/4 inch depth in the last sample. No fungi were found in the three samples removed from the 8,850 foot elevations on March 2, May 26, or June 24.

Figure 18.--The imperfect stage of a fungus was found on seeds of intermediate wheatgrass (upper left), slender wheatgrass (lower left), smooth brome (upper right), and mountain brome (lower right) (59-58).

"Depth of Planting" studies were removed from each elevation just as the soil was drying in the spring of 1959. At the lower elevation all depths were removed on May 1. At the 7,000 foot elevation, the 1/3 to 6 inch depths inclusive were removed on May 13, and the 1 foot and 2 foot depths were removed on June 9. At the 8,850 elevation the 1/3 through 4 inch depths were removed on June 24, and the 6 inch through 2 foot depths were removed on July 6.

Numbers of seeds infected with fungi when the seeds were removed from the soil varied with species, site, and depth of planting. As shown in table 4, fungi were most abundant at the lower elevation and were absent at the upper site. Fungi were most abundant on the domestic smooth brome and intermediate wheatgrass seeds and seedlings. Seeds and seedlings of the native slender wheatgrass and native mountain brome were least infected. At the 5,500 foot site fungi were most abundant on seed at the 3/4 inch depth, the 1/3 inch depth, and the 2 foot depths, but were absent at 4 and 6 inch depths. Reasons for the absence of fungi at the 4 and 6 inch depths are believed to be closely related to the dry, cold soil at this depth in comparison to either the shallower or deeper soils. Seeds visibly infected with fungi usually did not begin to germinate, the seedlings were usually abnormal, and the shoot started to shrivel and turn brown. Only 5.3 percent of the smooth brome seeds planted at the 3/4 inch depth at the lower elevation on the October 20 planting date produced normal roots and shoots. However, at the 4 and 6 inch depths, where no fungi were observed, over 81.0 percent of these seeds developed normal roots and shoots.

Table 4 .--Percent of seed infected with a fungi when removed from soil at three sites just as accumulated moisture was depleted in the spring

Pltg. Depth	Date Pltd.	Sorenson's Field 1/				Majors Flat 2/				Headquarters 3/			
		Intermediate wheatgrass	Slender wheatgrass	Mountain brome	Smooth brome	Intermediate wheatgrass	Slender wheatgrass	Mountain brome	Smooth brome	Intermediate wheatgrass	Slender wheatgrass	Mountain brome	Smooth brome
1/3 in.	10/20	16.3	1.3	4.0	21.3	0	0	0	.7	0	0	0	0
3/4 in.	9/17	65.3	5.0	16.7	92.3	.7	0	0	3.7	0	0	0	0
3/4 in.	10/3	75.7	4.3	26.0	95.0	2.3	0	0	1.7	0	0	0	0
3/4 in.	10/20	23.7	5.0	6.7	92.3	1.3	0	0	1.7	0	0	0	0
3/4 in.	11/19	14.3	1.0	4.0	61.0	1.0	0	0	1.3	0	0	0	0
2 in.	10/20	0	0	0	4.3	0	0	0	0	0	0	0	0
4 in.	10/20	0	0	0	0	0	0	0	0	0	0	0	0
6 in.	10/20	0	0	0	0	0	0	0	0	0	0	0	0
1 ft.	10/20	2.3	.7	3.3	11.7	0	0	0	0	0	0	0	0
2 ft.	10/20	16.3	1.7	4.3	45.7	0	0	0	0	0	0	0	0

1/ Removed on May 1, 1959; 2/ Removed on May 13, 1959 except for 1 and 2 ft. depths on June 9, 1959; 3/ Removed on June 24, 1959 except that 1 and 2 ft. depths removed on July 6, 1959.

III-A-4. Seed germination and behavior in snow, sand, and soil

This study was established to provide additional information on the factors which may limit or curtail germination, emergence, and establishment of grasses from fall plantings under a deep winter snow cover. Treatments, procedures, and methods used were based on the studies conducted on Philadelphia Flat and Headquarters Station in the winters of 1956-1957 and 1957-1958.

These studies demonstrated that some seed of introduced and native grasses began to germinate and grow in the thawing soil under a winter snow cover. These studies also demonstrated that viability of some of the remaining seed had been reduced. This was especially noticeable on areas that flooded during rapid spring snowmelt. Seeds of four species, all harvested in 1958, were used in this study. Species used were: intermediate wheatgrass grown on the Frischknecht farm in Sanpete County, progeny of P-2327; a field collection of smooth brome grown in Ephraim Canyon at 8,850 feet; native slender wheatgrass from an elevation of 9,400 feet in Ephraim Canyon; and native mountain brome from an elevation of 10,000 feet in Ephraim Canyon. Seed of all species was harvested by hand and thoroughly cleaned. Seed was separated into units with 100 seeds of a single species per unit. Each unit was placed in a small nylon mesh bag and the bags were closed and stitched to prevent seed loss.

The study area was prepared during the late summer and fall of 1958. Four areas approximately 15 feet apart were cleared and staked so that sacks could be located after deep snow covered the site. Since

gophers had been a problem on this area, all animals on this and the surrounding area were trapped to destroy the existing population and reduce the winter migration into the study area.

Five "planting" treatments were used in this study. These included burying sacks under 3/4-inch of native soil, 4 inches of native soil, placing seed on the soil surface, planting under 3/4-inch of sand in a sand mound and suspending sacks in the snow approximately 4 inches above the soil surface. Sand mounds were made by building a frame 3 feet square and 5 inches high of galvanized wire screen supported by lath stakes at all corners and at intervals along the sides. This frame was filled with builders sand. Wooden frames 2 feet square and 6 inches high were made without tops or bottoms. Ends of the frames were solid but the sides were partly open to allow lateral movement of snow. Four nylon cords were stretched across the top of the frame and the sacks were stitched to the nylon cords as shown in figure 19.

Plantings were made on November 19, 1958, when the snow depth averaged 9 inches and the soil was lightly frozen to a depth of over 4 inches. Snow was removed from the plot areas. Plantings in the native soil were made in 3/4 and 4 inch pits dug prior to snowfall. The sacks were covered with unfrozen soil which had been removed from the pits and stored in plastic bags for this purpose. Similar planting procedures were used for planting in the sand mounds under 3/4 inch of sand. Frames with bags in place were placed on the native soil with the bottoms

Figure 19.--Seeds in bags placed to show respective positions when the area was covered by snow: under 3/4 inch of native soil (left stake), under 4 inches of native soil (right stake), on soil surface, under 3/4 inch of sand in sand mound and suspended on nylon cords approximately 4 inches above the soil surface (59-19).

of the bags suspended in the air about 4 inches above the soil surface. Bags placed on the soil surface were set in place and covered with snow to hold them in place. When all plantings were complete, a snow cover 9 inches deep was replaced over the plot.

Snow depth remained between 6 and 9 inches until the latter part of December when snow depth reached 18 inches but was over 22 inches from January 25 until May 7, 1959. Maximum temperature in the sand, on the soil surface, and in the top 4 inches of native soil did not reach 32°F. until March 17. Temperatures did not exceed 32°F. on any day until after March 26 when the temperature at the soil surface reached 33°F. The temperature at a depth of 3/4 inch in the native soil was the warmest and maximum daily temperatures frequently reached 33°F and occasionally reached 34°F. during the period prior to snowmelt on May 14, 1959. Maximum temperatures at the soil surface, in the sand, in the snow, and at a depth of 4 inches in the native soil seldom exceeded 32°F. prior to spring snowmelt.

The first sample of seed was removed on March 30 when the snow was still 39 inches deep. Some signs of gophers working were found but no damage to seeds or sacks was observed. Sacks in the snow were frozen, but some fungi could be seen on grass seeds. As shown in table 5, the only seed that had started to germinate was intermediate wheatgrass at the soil surface.

The second sample was removed on April 17 when the snow depth was still 25 inches. The soil was quite moist at least to the 4 inch depth in the soil. Seeds of intermediate wheatgrass, slender wheatgrass, and smooth brome started to germinate but roots or shoots had not penetrated the bags on this date.

Table 5 .—Percent germination in seed of four grasses placed in snow under 3/4 inch sand, on soil surface, under 3/4 inch soil and under 4 inches of soil, after a permanent winter snow was on the ground, when removed on three dates, just as the soil thawed (3/30), after soil thawed (4/17), and just before spring snowmelt (5/12)

Sampling Date		Planting Location				
		Sand	Snow	Surface	3/4 inch Soil	4 inch Soil
		-Percent				
	Intermediate wheatgrass					
3/30/59	On removal	0.0	0.0	3.0	0.0	0.0
	Complete	94.7	83.3	87.7	91.0	91.7
4/17/59	On removal	7.0	1.7	22.7	7.0	6.0
	Complete	92.3	86.0	91.7	91.0	86.7
5/12/59	On removal	41.7	7.7	28.3	63.3	79.7
	Complete	90.7	91.0	93.7	93.3	94.0
	Slender wheatgrass					
3/30/59	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	44.7	12.3	17.3	37.0	61.3
4/17/59	On removal	0.0	0.0	1.0	0.0	5.3
	Complete	31.3	17.0	29.3	59.3	51.7
5/12/59	On removal	8.7	0.0	0.0	83.0	78.0
	Complete	58.7	69.7	69.3	87.0	80.3
	Mountain brome					
3/30/59	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	0.3	1.3	0.3	0.0	0.7
4/17/59	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	0.7	1.0	0.0	3.7	0.0
5/12/59	On removal	6.0	0.0	0.0	18.7	6.0
	Complete	15.0	2.7	0.0	29.7	9.3
	Smooth brome					
3/30/59	On removal	0.0	0.0	0.0	0.0	0.0
	Complete	86.3	83.7	83.3	86.0	91.3
4/17/59	On removal	0.3	1.0	9.7	0.7	0.0
	Complete	84.3	85.0	86.3	85.0	86.0
5/12/59	On removal	10.3	8.3	16.3	12.0	7.0
	Complete	91.0	83.7	75.0	72.0	83.7

The third sample was removed on May 12. Snow was still about 12 inches deep over the undisturbed plots but was melting very rapidly. Seeds of intermediate wheatgrass and smooth brome at all locations had started to germinate. Seeds of the native slender wheatgrass and native mountain brome had started to germinate in the sand and at both depths in the native soil. No germination of these native grasses was found on the seed at the soil surface or suspended in the snow above the soil surface. Seeds removed on each sample date were taken to the laboratory where percent germination on removal date and length of root and shoot were determined. Seeds were placed on moist sand in small plastic boxes and germinated at 68-82°F. for an additional 31 days. Germination percents on removal and after 31 days, (complete), are shown in table 5. As shown in this table, seed dormancy in the native slender wheatgrass and native mountain brome had not been fully broken on the third sampling date, May 12, 1960.

On May15, 1959, just as the snow was melting, additional seed samples were removed from the soil surface, sand mound, and snow. Seeds in nylon bags were taken to the laboratory where they were dried and stored at room temperature and humidity. On July 16 seeds were removed from the bags and examined under a microscope. Seeds that had started to germinate were separated from those that had not produced a visible radicle or shoot. All seeds were placed on moist sand in small plastic dishes and germinated at 48-82°F. for an additional 34 days. Seeds that had germinated or started to germinate prior to removal absorbed water. Roots on some of these seeds firmed and appeared to be living, but

many of them disintegrated in 1 to 4 days. Some of the seeds that had produced visible roots prior to drying developed a shoot but did not produce another root. As shown in table 6 many of the native mountain brome and native slender wheatgrass seeds would not germinate in the field or during the 34 day period in the germinator but still appeared to be good seeds that were dormant.

Table 6 .--Subsequent germination of seed of four species, which had started to germinate prior to removal from the soil surface, sand or snow, just prior to snowmelt in the spring; dried and stored at room temperature for 2 months and compared with germination of seeds that did not show visible germination on the removal date and fresh seed from stock supplies

Location	Total No. of seeds	Subsequent Germination: Total additional	Healthy seedling	None	Apparent good seed remaining
		Percent			
Intermediate Wheatgrass					
Laboratory - stock seed	300	95.0	95.0	5.0	2.0
In Snow	600				
Visible germination	79	48.3	43.2	51.7	0.0
No visible germination	521	74.3	72.4	25.7	10.0
Sand - 3/4 inch	600				
Visible germination	240	34.4	27.1	65.6	0.0
No visible germination	360	72.2	71.6	27.8	8.6
Soil Surface Under Snow	300				
Visible germination	92	8.7	7.6	91.3	0.0
No visible germination	208	74.0	74.0	26.0	1.9
Slender Wheatgrass					
Laboratory - stock seed	300	74.7	74.7	25.3	25.0
In Snow	600				
Visible germination	0	-	-	-	-
No visible germination	600	9.5	9.5	90.5	77.8
Sand - 3/4 inch	600				
Visible germination	98	35.8	35.8	64.2	0.0
No visible germination	502	19.1	19.0	80.8	65.0
Soil Surface Under Snow	300				
Visible germination	4	0.0	0.0	100.0	0.0
No visible germination	296	12.2	12.2	87.8	67.9
Mountain Brome					
Laboratory - stock seed	300	46.3	46.3	53.7	52.0
In Snow	600				
Visible germination	0	-	-	-	-
No visible germination	600	0.0	0.0	100.0	93.7
Sand - 3/4 inch	600				
Visible germination	31	34.8	29.8	65.2	0.0
No visible germination	569	5.2	5.2	94.8	78.5
Soil Surface Under Snow	300				
Visible germination	0	-	-	-	-
No visible germination	300	3.0	3.0	97.0	86.3

Table 6 4.--(cont.)

Location	Total No. of seeds	Subsequent Germination: Total additional	Healthy seedling	None	Apparent good seed remaining
		Percent			
Smooth Brome					
Laboratory - stock seed	300	90.7	90.7	9.3	3.0
In Snow	600				
Visible germination	90	37.4	30.4	62.6	0.0
No visible germination	510	59.4	57.5	40.6	0.6
Sand - 3/4 inch	600				
Visible germination	73	49.5	43.7	50.5	0.0
No visible germination	527	57.6	54.4	42.4	2.0
Soil Surface Under Snow	300				
Visible germination	35	25.7	25.7	74.3	0.0
No visible germination	265	63.8	63.8	36.2	0.8

III-A-5. Seed germination and seedling emergence studies at high elevations

Tests were made on 36 species of grasses, forbs, or shrubs to determine when seeds germinate and emerge at two high elevation sites. This study was divided into two phases. In one phase, the germination of seeds in nylon bags, planted in the fall under snow or soil, on two dates of planting, was checked at intervals during the winter and spring. In the second phase, seed of each species was planted in rows in the fall, and emergence and mortality counts were made at intervals during the snow free period.

Seeds used were freshly harvested from the 1958 crop except that 1 year or older seed lots of intermediate wheatgrass, slender wheatgrass, mountain brome and smooth brome were also included for comparison. Where practical seeds were harvested from high elevation areas similar to the study sites. Species used and pertinent information on date and seed source are included in table 7.

The two study areas are only about 2 miles apart, but slope and enclosures are quite different: (1) Philadelphia Flat - is located on a wide near level terrace at an elevation of approximately 10,000 feet. This area is frequently snow covered from the first heavy snow in October or November, until the air temperature is relatively high the following May or early June, when the frost danger is low. When dry or unfrozen soil is covered by snow in the fall, the soil may remain at or above freezing throughout the winter. This area is subjected to flooding during rapid snowmelt in the spring. Flooding may also cause

a breakdown in the soil structure, which in turn may decrease soil aeration, reduce water holding capacity, and favor crusting. (2) Summit Enclosure - is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth, during the winter period on this area, is usually less than on Philadelphia Flat, due to increased melting in the fall and spring, and wind action. Soil may be frozen during the winter. When the soil is bare or snow covering is shallow, alternate freezing and thawing may produce heaving, frost damage, or rapid drying of the surface soil around the seeds. Flooding has been observed, but does not appear to be a serious problem on this site.

The study areas used were prepared during the late summer and fall of 1958. Since gophers had been a problem on these areas the previous year, study areas were thoroughly trapped. The six areas used for the sack study were staked with poles 8 feet long so that samples to be removed after a deep snow was on the ground could be accurately located.

Phase 1, a study of the germination of fall planted seeds of domestic and native plants, during the fall, winter, and spring, was only conducted at Philadelphia Flat. One hundred seeds of a single species were placed in nylon bags and the bags were closed and stitched to prevent seed loss. Large seeds were placed in nylon bags with a rather open mesh. Species with small seeds were placed in bags made from light weight nylon material with a fine mesh. An early fall planting was made under 3/4 inch of soil at six separate locations on September 17, 1958, with an extra sample unit placed at two of

these locations, to be removed when the later planting was made. A second planting was made on November 19 after a permanent winter snow cover, 8 inches in depth, covered the ground. On the second planting date an additional planting was made under 3/4 inch of soil at each of the six original locations and the snow cover was replaced. At four of these same locations seeds in nylon bags were also placed directly on the soil surface and the snow cover was placed directly on the seeds. Seeds in nylon bags were removed at intervals during the winter and spring to follow germination. Seeds removed from this site were packed in snow until they could be counted in the laboratory.

Laboratory germination tests at 68-82°F. were initiated on all seed lots on October 27 but mold soon developed on seed of many species. Additional lots of seeds treated with Orthrocide 75, according to directions, were placed in the germinator on November 26, 1958. An additional laboratory test was made on July 31, 1959 after storage at room temperatures for approximately 1 year but these results and the results from the October 27, 1958 tests are not included in this report.

The two samples planted as extras on the first planting date were removed on November 19, 1958 when the second samples were planted. These samples were taken to the laboratory and examined for prior germination and then placed in the germinator. On this removal date only the seed of desert wheatgrass and the 1957 seed of intermediate wheatgrass had started to germinate from the early fall planting.

The soil at Philadelphia Flat was not frozen when the planting under snow was made on November 19. Additional snow fall in November and early December was very light and average snow depth was only 6 inches deep. All plantings were still covered with snow but the soil had frozen to a depth of about 2 inches. On December 15 the snow depth had increased to 9 inches but the low temperatures had frozen the soil to an average depth of about 3 inches. A heavy snow fell on December 27, 1959. On January 19 the snow depth averaged 20 inches and the soil was frozen to a depth of 1 to 3 inches, depending on site. In general, the soil was too dry to freeze solid and was usually granular in structure,

The first full seed sample was removed on February 25, 1959. The soil on the study area was still slightly frozen and had a granular structure with ice crystals scattered in the top 3 inches of soil. Eleven species from the early fall planting had started to germinate. Six of these species had also started to germinate from the late fall planting under 3/4 inch of soil and four of these same species had started to germinate on the soil surface.

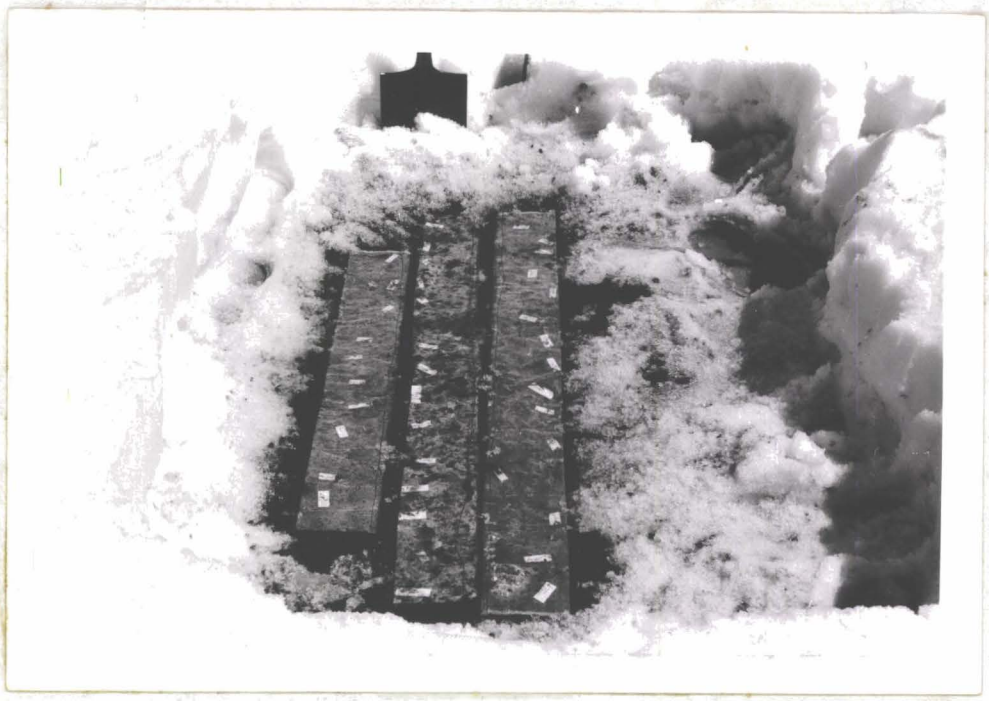
The second seed sample was removed from Philadelphia Flat on March 31, 1959. Average snow depth was 54 inches. Most of the soil was still dry and frozen but a few spots had thawed. Considerable fungi was observed on seed at the soil surface and a little on seed that was buried under the soil.

By April 13 the snow on the study area had dropped to an average depth of 35 inches. The surface soil had thawed and was moist to wet, but a few ice crystals were found in patches at 1 to 2 inches.

By April 20 additional snowfall had increased the snow depth to 40 inches. The soil was quite moist to wet and native lupine and other seedlings could be seen growing in the soil. By April 27 when the third seed sample was removed, snow depth had increased to 48 inches. Snow depth gradually decreased except for temporary increases due to additional snowfall. Snow depths in the winter of 1958-1959 are shown below.

Date	Snow Depth (Inches)
Nov. 14	8
Dec. 8	6
Dec. 9	9
Jan. 19	20
Feb. 25	51
Mar. 31	54
Apr. 13	35
Apr. 27	48
May 4	43
May 11	36
May 20	24
May 25	18
May 29	12
May 31	7
June 1	Patchy
June 3	0

The fourth sample was removed from Philadelphia Flat on May 29 when the snow depth over the seeds was only 12 inches deep. The soil was very wet. Growth was visible on seed of many species on seed removed from the soil surface and from below 3/4 inch of soil (figures 20 and 21). Seed germination from the sample from the early fall planting and the planting on the soil surface and under soil after the permanent winter snow are shown in table 7.



Figures 20 and 21.--The fourth seed samples were removed from Philadelphia Flat on May 29, just before snowmelt in the spring of 1959. The upper photo shows the nylon bags containing seeds that had been placed directly on the soil surface. The lower photo shows the nylon bags containing seeds that had been covered with 3/4 inch of soil (59-53 and 59-55).

Table 7 .- Percent germination for seeds of 40 species or strains planted under 3/4-inch of soil in early fall, under 3/4-inch of soil after permanent winter snow and placed on the soil surface after permanent snow on Philadelphia Flat when removed just before snowmelt in the following spring

Species, Location and Date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Snow: Soil	Permanent Snow: Snow	Check 2/ Lab.
Grasses					
Agropyron desertorum - Mandan, North Dakota. 1955. Nordan, F.C. 33,091	Removed	61.0	67.0	70.0	-
	Final	65.0	73.0	73.0	82.0
Agropyron intermedium - Northrup, King, SLC. Lot D6-1 Washington. 1956	Removed	79.0	76.0	71.0	-
	Final	80.0	74.0	92.0	98.0
Agropyron intermedium - Frischknecht Farm. Sept. 5, 1958. El. 5,500 ft.	Removed	67.0	82.0	35.0	-
	Final	82.0	93.0	98.0	96.0
Agropyron trachycaulum - Dungeon Ephraim Can. Sept. 17, 1957. El. 9,400 ft.	Removed	95.0	92.0	3.0	-
	Final	95.0	95.0	75.0	55.0
Agropyron trachycaulum - Dungeon Ephraim Can. Aug. 13, 1958. El. 9,400 ft.	Removed	95.0	87.0	4.0	-
	Final	91.0	75.0	86.0	35.5
Alopecurus pratensis - Summit Enclosure. Aug. 11, 1958. El. 10,200 ft.	Removed	65.0	55.0	47.0	-
	Final	97.0	95.0	75.0	94.5
Arrhenatherum elatius - Summit Enclosure. Aug. 27, 1958. El. 10,200 ft.	Removed	68.0	44.0	51.0	-
	Final	72.0	52.0	49.0	84.5
Bromus carinatus - Bluebell Flat, Ephraim Can. Sept. 12, 1957. El. 9,100 ft.	Removed	37.0	54.0	9.0	-
	Final	31.0	63.0	12.0	51.5
Bromus carinatus - Cattle Pasture, Ephraim Can. Aug. 14, 1958. El. 10,100 ft.	Removed	10.0	18.0	0.0	-
	Final	10.0	29.0	1.0	3.0
Bromus inermis - Northrup, King, SLC. Manchar 1956. Lot D6-33 Washington	Removed	31.0	39.0	46.0	-
	Final	39.0	64.0	72.0	92.0
Bromus inermis- Headquarters Ephraim Can. Sept. 8, 1958. El. 8,850 ft.	Removed	12.0	10.0	29.0	-
	Final	86.0	74.0	84.0	92.5
Bromus tomentellus - Summit Enclosure. Aug. 14, 1958. El. 10,200 ft.	Removed	97.0	81.0	78.0	-
	Final	97.0	84.0	85.0	98.5
Dactylis glomerata - Summit Enclosure. Sept. 2, 1958. El. 10,200 ft.	Removed	75.0	61.0	45.0	-
	Final	86.0	94.0	79.0	91.0
Hesperochloa kingi - Buck Ridge, Ephraim Aug. 11, 1958. El. 9,700 ft.	Removed	25.0	19.0	0.00	-
	Final	52.0	30.0	27.0	89.0

Species, Location, and date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Soil	Snow Snow	2/ Check Lab.
Grasses (Cont.)					
Stipa columbiana - Cattle Pasture Ephraim Can. Aug. 18, 1958. El. 10,100 ft.	Removed	92.0	78.0	2.0	-
	Final	92.0	92.0	86.0	1.0
Stipa lettermani - Summit Enclosure. Aug. 18, 1958. El. 10,200 ft.	Removed	82.0	66.0	4.0	-
	Final	83.0	84.0	80.0	18.0
Forbs and Shrubs					
Aquilegia coerulea - Philadelphia Flat. Aug. 6, 1958. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	98.0	93.0	94.0	89.5
Claytonia lanceolata - Philadelphia Flat. July 7, 1958. El. 10,000 ft.	Removed	30.0	26.0	37.0	-
	Final	32.0	26.0	37.0	0.0
Collomia linearis - Philadelphia Flat. Aug. 6, 1958. El. 10,000 ft.	Removed	66.0	74.0	68.0	-
	Final	66.0	74.0	68.0	0.0
Delphinium nelsonii - Philadelphia Flat. July 26, 1958. El. 10,000 ft.	Removed	64.0	60.0	27.0	-
	Final	64.0	61.0	28.0	0.0
Descurainia richardsonii incisa - Philadelphia Flat. Aug. 11, 1958. El.10,000 ft.	Removed	61.0	45.0	50.0	-
	Final	62.0	45.0	51.0	2.0
Erythronium grandiflorum - Philadelphia Flat. July 29, 1958. El. 10,000 ft.	Removed	15.0	15.0	12.0	-
	Final	15.0	16.0	13.0	0.0
Geranium richardsonii - Philadelphia Flat. Aug. 11, 1958. El. 10,000 ft.	Removed	57.0	52.0	37.0	-
	Final	59.0	55.0	39.0	39.0
Gilia pulchella - Philadelphia Flat. Aug. 11, 1958. El. 10,000 ft.	Removed	72.0	91.0	75.0	-
	Final	75.0	91.0	79.0	9.5
Lomatium nuttallii - Philadelphia Flat. Aug. 18, 1958. El. 10,000 ft.	Removed	35.0	13.0	15.0	-
	Final	37.0	13.0	15.0	0.0
Lupinus alpestris - Philadelphia Flat. Aug. 5, 1958. El. 10,000 ft.	Removed	39.0	12.0	11.0	-
	Final	39.0	14.0	11.0	10.5
Madia glomerata - Philadelphia Flat. Aug. 27, 1958. El. 10,000 ft.	Removed	96.0	76.0	87.0	-
	Final	96.0	82.0	88.0	0.0
Mertensia leonardi - Cattle Pasture Ephraim Can. Aug. 6, 1958. El. 10,100 ft.	Removed	89.0	78.0	42.0	-
	Final	89.0	82.0	46.0	0.0
Orthocarpus tolmiei - Philadelphia Flat. Aug. 11, 1958. El. 10,000 ft.	Removed	88.0	55.0	25.0	-
	Final	88.0	60.0	25.0	0.0
Osmorhiza occidentalis - Philadelphia Flat. Aug. 27, 1958. El. 10,000 ft.	Removed	10.0	3.0	4.0	-
	Final	10.0	3.0	4.0	0.0

Species, Location, and date of Collection	Date 1/	Planting Treatment: Early Fall Soil	Permanent Soil	Snow	2/ Check Lab.
Forbs and Shrubs (cont.)					
Penstemon rydbergii - Philadelphia Flat. Sept. 8, 1958. El. 10,000 ft.	Removed	94.0	97.0	92.0	-
	Final	94.0	97.0	93.0	0.5
Polygonum douglasii - Summit Enclosure. Aug. 11, 1958. El. 10,200 ft.	Removed	27.0	47.0	90.0	-
	Final	35.0	48.0	90.0	0.0
Polemonium foliosissimum albiflorum - Philadelphia Flat. Aug. 27, 1958. El.10,000 ft.	Removed	45.0	20.0	0.0	-
	Final	45.0	20.0	1.0	0.0
Potentilla pulcherrima - Philadelphia Flat. Aug. 18, 1958. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	77.0	80.0	91.0	97.0
Ribes montigenum - Philadelphia Flat. Aug. 14, 1958. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	0.0	0.0	0.0	0.0
Rumex mexicanus - Philadelphia Flat. Aug. 27, 1958. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	96.0	47.0	82.0	92.5
Stellaria jamesiana - Philadelphia Flat. Aug. 11, 1958. El. 10,000 ft.	Removed	81.0	71.0	43.0	-
	Final	83.0	71.0	46.0	0.5
Taraxacum officinale - Philadelphia Flat. July 19, 1958. El. 10,000 ft.	Removed	55.0	61.0	50.0	-
	Final	91.0	63.0	62.0	91.0
Valeriana edulis - Philadelphia Flat. Aug. 6, 1958. El. 10,000 ft.	Removed	0.0	0.0	0.0	-
	Final	92.0	90.0	89.0	46.0
Viola nuttallii linguaefolia - Philadelphia Flat. July 21, 1958. El. 10,000 ft.	Removed	59.0	74.0	45.0	-
	Final	59.0	74.0	45.0	0.0

1/ Removed from soil and snow on 5/29/59 and Final after laboratory germination for 31 days.

2/ Check lot in germinator on 11/26/59.

The fifth sample, containing seeds only from the early and late fall plantings under soil were removed on June 10, approximately 7 days after snowmelt. All species except columbine, potentilla, and rumex had started to germinate when the seeds were removed from the soil.

The sixth sample, also containing seeds only from the early and late fall plantings under 3/4 inch of soil, was removed on June 24, approximately 3 weeks after snowmelt. All species except the columbine and rumex had started to germinate when the seeds were examined on this date.

This study has shown that conditions necessary for seed germination vary with species. Seeds of some of the domestic grasses, crested wheatgrass, intermediate wheatgrass, and smooth brome in particular, began to germinate as soon as moisture was adequate, even though temperatures around the seed often went below freezing at night. Soil temperatures at 3/4 inch depth in the fall of 1958 varied from a high of 75 to a minimum of 23°F. Seeds of some native and introduced grasses and forbs were slower to begin germinating under the low night temperatures and limited moisture. Typical of these species were Alopecurus, orchardgrass, Geranium, and lupine. Seed germination in many other native plants remained low until seed dormancy was broken by the cold moist condition existing in the unfrozen soil under a deep snow. Typical of these plants were mountain brome, slender wheatgrass, native Stipa, and tarweed. Seeds of another group did not germinate in the fall or

winter while the soil was cool, but germinated after the soil warmed up in the spring, or germinated readily at 68-82°F. in the laboratory. Typical of these latter group were Aquilegia, Potentilla, and Valeriana.

In general, germination of seed placed on the soil surface under the snow cover was slower to start, than comparable seed lots placed under 3/4 inch of soil on the same planting date.

Phase 2, a study of seedling emergence and mortality was conducted at Philadelphia Flat and also at the Summit Enclosure. Row plantings with 100 seeds of a single species and three replications, were made at each of the two study areas on September 17, 1958. All species were planted at random, except that the two age groups of seed of intermediate wheatgrass, slender wheatgrass, mountain brome, and smooth brome were planted side by side. Large seeds were planted at a maximum depth of 2 cm. and small seeds were planted at a maximum depth of 1 cm. Each furrow was 5 feet long. Furrows were made by loosening the soil and shaping a shallow furrow with the bottom of a V-shaped piece of aluminum that was 5 feet 2 inches long. Uniform distribution of seed was obtained by first uniformly distributing the seed along a marked 5 foot row length on the upper side of the V-shaped piece of aluminum, then tipping the seed directly into the bottom of the furrow. Soil was placed over the seeds to the proper depth and firmed.

At the Summit Enclosure, the soil had been dry to October 19. The first snow fell on the area on November 14 and snow cover was intermittent until December 27, when a heavy storm put down 18 inches of new snow. The soil was frozen to a depth of 4 to 6 inches on December 1,

and to a depth of approximately 1 foot by December 15. By March 31, 1959 the snow on south and west slopes had settled. Currant bushes on ridges, road markers and road cuts were often visible. By April 13 snow depth was between 9-18 inches over the plot area, but did not drop below this depth, due to additional snowfall, until after May 11.

By May 18, the Summit Enclosure was nearly free of snow and very wet. No sign of grass seedlings could be seen but a few native weed seedlings near the plot area were seen. This area was covered by shallow snow on May 19, 21, and 23, but was free of snow on May 27.

Seedling emergence and seedling mortality counts were made on each area about June 15, June 30, July 15, August 13, and September 22. On each date the newly emerged seedlings were marked with color coded toothpicks. Where seedlings had died an uncolored toothpick was placed beside the colored toothpick. Total emerged seedlings and seedling mortality on June 15, July 15, and September 22 for all species are shown in table 8. As shown in figure 22, seedling emergence on the Philadelphia Flat study area was high. Total seedling emergence on the Philadelphia Flat study area averaged about five times higher than at the Summit Enclosure study area. The primary reason appeared to be the severe freezing and thawing at the Summit Enclosure.

In general, the grasses produced better stands than the forbs and all grass species produced some seedlings at both sites. Five forbs and the single shrub failed to produce a single seedling at Philadelphia Flat. Nine forbs and the single shrub species failed to produce a single seedling at the Summit Enclosure. Species that were slow to start

Table 8 .- Average field emergence per 100 fall planted seeds and seedling mortality at two locations on three dates: after spring snow-melt (6/15), mid-summer (7/15), and early fall (9/22)

Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring	Summer	Fall	Spring	Summer	Fall
Grasses		6/15	7/15	9/22	6/15	7/15	9/22
		Percent					
Agropyron desertorum	Emergence	18.0	21.3	21.3	4.3	4.7	6.7
	Mortality		1.7	2.7			
Agropyron intermedium 1956	Emergence	29.3	33.0	33.3	8.0	8.3	12.7
	Mortality		3.7	4.7		1.7	1.7
Agropyron intermedium 1958	Emergence	50.0	58.0	58.0	12.3	14.3	18.0
	Mortality		5.3	6.7		1.0	1.3
Agropyron trachycaulum 1957	Emergence	66.0	71.7	73.0	9.7	10.7	14.0
	Mortality		2.0	3.3		0.7	0.7
Agropyron trachycaulum 1958	Emergence	61.7	65.3	65.7	11.7	15.3	23.7
	Mortality		1.3	1.7		0.3	0.3
Alopecurus pratensis	Emergence	15.3	20.3	20.3	2.7	3.0	3.7
	Mortality		3.3	4.7		0.7	0.7
Arrhenatherum elatius	Emergence	42.0	49.7	49.7	4.0	4.7	12.0
	Mortality		2.7	4.0		0.3	0.7
Bromus carinatus 1957	Emergence	52.7	57.7	58.7	5.0	6.0	10.7
	Mortality		3.3	4.3		0.3	0.3
Bromus carinatus 1958	Emergence	24.3	31.0	31.0	3.0	3.0	4.7
	Mortality		1.0	1.3		0.0	0.0
Bromus inermis 1956	Emergence	27.7	34.0	36.7	4.3	4.3	7.0
	Mortality		2.0	3.3		1.0	1.7
Bromus inermis 1958	Emergence	26.7	36.7	39.0	8.0	9.0	19.0
	Mortality		3.0	5.0		1.3	1.3
Bromus tomentellus	Emergence	55.0	60.0	60.0	13.0	13.7	22.3
	Mortality		2.7	5.0		3.0	3.7
Dactylis glomerata	Emergence	20.7	28.0	28.0	2.0	2 .0	13.7
	Mortality		3.0	4.7		1.3	1.7
Hesperochloa kingi	Emergence	16.0	19.0	19.0	4.3	4.7	6.3
	Mortality		1.7	3.3		1.0	1.3

Species		Locations: Philadelphia Flat Spring 6/15	Philadelphia Flat Summer 7/15	Philadelphia Flat Fall 9/22	Summit Enclosure Spring 6/15	Summit Enclosure Summer 7/15	Summit Enclosure Fall 9/22
Grasses (continued)							
		- - - - - - - - - - Percent - - - - - - - - - -					
Stipa columbiana	Emergence	43.7	47.7	49.7	1.3	2.3	2.3
	Mortality		1.3	2.0		1.3	1.3
Stipa lettermani	Emergence	42.0	45.0	46.0	1.3	1.7	1.7
	Mortality		3.7	3.7		0.0	0.0
Forbs and Shrubs							
Aquilegia coerulea albiflora	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Claytonia lanceolata	Emergence	16.0	17.0	17.0	0.0	0.0	0.0
	Mortality		15.3	17.0		0.0	0.0
Collomia linearis	Emergence	36.0	42.3	42.3	0.0	0.0	0.0
	Mortality		2.3	2.7		0.0	0.0
Delphinium nelsonii	Emergence	6.7	6.7	6.7	1.0	1.0	1.0
	Mortality		3.3	6.7		0.7	1.0
Descurainia richardsonii incisa	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Erythronium grandiflorum	Emergence	0.7	0.7	0.7	0.0	0.0	0.0
	Mortality		0.7	0.7		0.0	0.0
Geranium richardsonii	Emergence	20.3	22.0	22.0	3.7	4.0	4.0
	Mortality		2.0	3.0		0.7	1.0
Gilia pulchella	Emergence	0.0	11.0	11.3	0.0	0.3	0.3
	Mortality		1.3	1.7		0.3	0.3
Lomatium nuttallii	Emergence	13.7	14.0	14.3	1.3	1.3	1.7
	Mortality		0.7	1.7		1.0	1.0
Lupinus alpestris	Emergence	21.7	22.0	22.0	12.3	12.7	12.7
	Mortality		6.3	18.7		5.0	11.7
Madia glomerata	Emergence	41.3	43.3	43.3	0.3	0.3	0.3
	Mortality		0.7	6.3		0.0	0.0
Mertensia leonardi	Emergence	21.3	23.0	23.0	1.0	1.0	1.0
	Mortality		1.0	410		0.3	0.3
Orthocarpus tolmiei	Emergence	0.7	2.3	2.3	0.0	0.0	0.0
	Mortality		0.7	1.7		0.0	0.0
Osmorhiza occidentalis	Emergence	7.0	8.3	8.3	1.0	1.0	1.0
	Mortality		2.0	2.3		1.0	1.0

Species		Locations					
		Philadelphia Flat			Summit Enclosure		
		Spring	Summer	Fall	Spring	Summer	Fall
Forbs and Shrubs (cont.)		6/15	7/15	9/22	6/15	7/15	9/15
		Percent					
Penstemon rydbergii	Emergence	2.3	3.0	3.0	1.0	1.0	1.0
	Mortality		2.0	2.3		1.0	1.0
Polygonum douglasii	Emergence	51.0	55.0	55.0	1.3	1.3	1.3
	Mortality		6.7	10.3		0.7	1.0
Polemonium foliosissimum albiflorum	Emergence	3.0	9.0	9.0	2.3	2.3	2.3
	Mortality		1.3	2.0		1.3	1.7
Potentilla pulcherrima	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Ribes montigenum	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Rumex mexicanus	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Stellaria jamesiana	Emergence	40.3	42.0	42.0	12.0	12.3	12.3
	Mortality		5.3	14.7		5.3	7.3
Taraxacum officinale	Emergence	0.0	0.0	0.0	0.0	0.0	0.0
	Mortality		0.0	0.0		0.0	0.0
Valeriana edulis	Emergence	12.0	14.7	14.7	7.0	7.0	7.7
	Mortality		3.7	8.7		3.0	3.3
Viola nuttallii linguaefolia	Emergence	43.7	47.7	47.7	2.0	3.7	3.7
	Mortality		2.0	7.0		0.3	1.7

Figure 22.--Many grasses and forbs produced good stands on the Philadelphia Flat area on August 14, 1959 (59-71).

germinating in the sack study at Philadelphia Flat were among the ones that failed to produce stands on both sites except for Valeriana edulis. Species failing to produce stands on Philadelphia Flat also failed to produce stands on the Summit Enclosure. Seeds of Taraxacum officinale failed to produce stands on both sites but many seedlings of this species were growing under established plants where the microclimate was more favorable (figure 23).

Figure 23.--Seedlings of Taraxacum officinale were very numerous near established plants which shaded the soil and altered the microclimate. No seedlings of this plant were found on bare exposed soil between established plants or in the row plantings at the Summit Enclosure or on Philadelphia Flat (59-127).

III-A-6. Vegetative growth of some cool season plants as affected by moisture and temperature

The annual growth and "dormancy" of cool season perennial grasses and forbs is cyclic in nature. In the Intermountain Region most plant growth is made in the spring and early summer months. With many plants secondary herbage growth is made during the fall months when the summer foliage is drying or with the return of favorable moisture. Part or all of this secondary growth may persist throughout the winter and active early spring growth may begin under a deep snow cover several weeks before the snow melts in the spring.

Plant growth periods are largely determined by available moisture, soil temperature, air temperature, snow depth, and other climatic conditions. Bunch grasses: crested wheatgrass, orchardgrass, tall oatgrass, slender wheatgrass, mountain brome, and similar grasses produced abundant basal leaves when conditions were especially favorable in the fall. Greenish-yellow leaves over 5 inches long have been measured. However, when fall temperatures were low or moisture restrictive, secondary growth was limited to production of shoots protected by old growth, soil or organic material.

Sodgrasses: smooth brome, reed canary, and intermediate wheatgrass produced rhizomes which emerged and produced new shoots when conditions were favorable in the fall, but when temperatures were low the terminal buds remained just below the soil surface until the soil thawed in the spring. Smooth brome shoots over 3 inches long have been observed protruding into the snow when the snow depth was still 68 inches. Figure 24 shows smooth brome shoots over 5 inches long on the day snow melted in the spring of 1959.

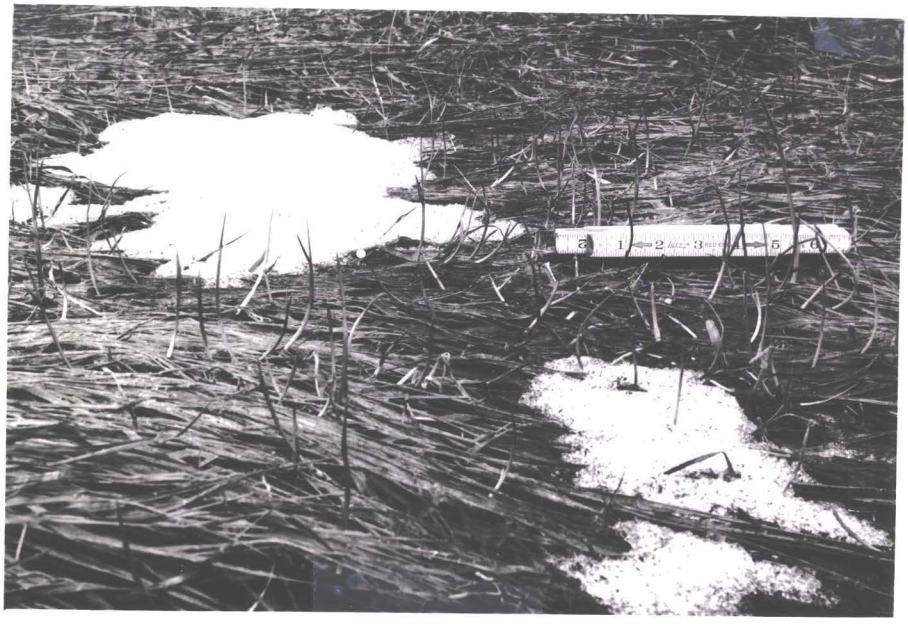


Figure 24.--Smooth brome shoots were slightly over 5 inches long when the snow melted from the Headquarters Nursery in the spring of 1959 (59-12).

Forbs such as Richardson geranium, niggerhead, and edible valerian formed new buds in the crown during the fall which persisted and elongated under the snow. These buds were usually protected by old growth, soil or organic material. The tips of some plants were exposed and outer bracts were leaflike and green. Rhizomatous forbs: yarrow, Rydberg penstemon, sweetsagebrush, and aster produced rhizomes or shoots in the fall but the terminal buds usually remained at or just below the soil surface until the snow melted. Still other forbs such as tinpiute gilia, Arabis, and Thalespi produced green basal leaves that persisted throughout the winter months.

Plants producing bulbs, tubers, or corms produced roots and started to grow in the fall. When the soil under the snow was frozen, little or no growth took place during the months of December to February. However, even when the soil below the snow was frozen to a depth of several inches in the late fall and winter months the soil thawed in late February or March. When the soil thawed, shoots and rhizomes began to elongate and often pushed into the snow. Some plants of spring beauty protruded into the snow over 3 inches and some troutlily plants protruded up into the snow more than 5 inches. Figure 25 shows plants of low larkspur that had pushed through the soil surface under a deep snow cover.

Figure 25.—Plants of low larkspur that emerged under a deep snow cover. The plant on right side is typical of plants that had just emerged from the soil. The middle and left plants show the first leaf starting to open and the elongation of the stock (59-3).

III-B. Depleted Sites at High Elevation

III-B-1. Pocket gophers on rangelands

Pocket gophers directly damage planted and native grasses and forbs by eating or destroying leaves, crowns, roots, or indirectly damage these plants by covering seeds, seedlings, or established plants with winter soil casts or summer mounds. Workings by these animals have been numerous on most harsh sites at high elevations in Utah where the vegetation has been depleted. Gopher activities have been followed and studied in conjunction with other work because of the damage these animals have done to seeded stands, revegetation studies and especially to the seed germination studies conducted under snow.

High gopher populations have been observed on many depleted high elevation sites. Pocket gophers were trapped in the fall of 1957, 1958, and 1959 on and near several revegetation study areas at approximately 10,000 feet in central Utah. Records were not kept on animal numbers in the fall of 1957 but record of total animals caught were kept on the area of about 4 acres on Philadelphia Flat. Trapping on this area started in September and continued until the end of November. A total of 63 animals or 15.8 gophers per acre were trapped. Many of these animals were small and were probably young adults but age or sex of animals was not recorded.

A record of gophers caught on the 4 acre area trapped in 1958 was also made during the period June 8 to November 30, 1959. During this period 46 adults and 56 small gophers, or a total of 102 animals were caught for an average of 25.5 gophers per acre. In addition four weasels were caught in traps on this area. Apparently the weasels

entered the open holes made when the traps were set and were caught as they attempted to leave the burrow. All traps were set to release only by an outward push and all weasels were caught with the head nearest the burrow opening. No gophers were caught and no evidence of gophers were found in the burrows after a weasel had been trapped, indicating the weasel had killed the gopher that lived in the burrow.

The activity of gophers during the fall and winter months, especially after snow covers the ground, appears to be largely determined by soil temperature and moisture. In the fall of 1956, 1957, 1958, and 1959 many mounds were made after the soil was moistened. In the fall of 1956, 1957, and 1959, just after the first snow and the soil was frost free, pocket gopher activity was marked. In the fall of 1958 only limited activity was noted when the soil froze before the first snow fell. Moderate gopher activity was observed in November, December, and January 1957 and 1958, but only limited activity was observed in 1958-1959 and also in 1959-1960 when the soil was frozen.

Gopher activity in the snow above the soil surface increased markedly after the February-March period of 1957, 1958, and 1959 and continued until snowmelt in the spring. The surface soil was frozen at high elevations in 1960 and accelerated gopher activity in the snow was not observed until March. The increased activity in the February-March period appears to be related to thawing of the soil when it has been frozen, an increase in temperatures of the surface soil and snow near the soil surface, a depletion of stored food reserves, additional food supply provided by an elongation of grasses and forbs and a need for storage space for soil and waste material.

A number of nests and food caches have been observed. Most of these have been at least 6 inches above the soil surface but in the spring of 1959 several nests were found just above the soil surface, figure 26, or in shallow excavations below the soil surface as shown in figure 27. On June 5, 1957 many soil casts and nests and a few food caches were found from 18 to 22 inches above the soil surface at Franklin Basin in Logan Canyon. A few scattered nests and food caches from 15 to 26 inches above the ground have been found at high elevations in Ephraim Canyon in 1957, 1958, and 1959. Nests found in the snow have usually been lined with dried grass or shredded bark.

Most of the burrows and soil casts observed in the snow were within 3 inches of the soil surface but one cast, 27 inches above the soil surface, was found in the spring of 1958. Gopher damage was rather severe on the study areas on Philadelphia Flat in the spring of 1957, 1958, and 1959. Where casts were placed in the snow on or near the soil surface the casts often followed depressions in the soil such as furrows. On furrowed plots where gophers were active, from 11 to 37 percent of the drill rows in the bottoms of the furrows were covered with soil casts. These casts were usually 1½ to 2½ inches in diameter; thus seeds and seedlings were often covered with 2 to 3 inches of soil when casts were placed in the bottom of the furrows directly over the seed. Number of seedlings were decreased from 35 to 90 percent where soil casts covered the seed row. Some damage to established plants was observed when casts covered the crowns but mortality of these plants did not appear to be high (figure 28).

Figures 26 and 27.--Gopher nests found in the snow have usually been found at least 6 inches above the soil surface, but in the spring of 1959 some nests were found at or just above the soil surface, upper plots, and three nests were found in shallow excavations as shown in the lower photo (59-59 and 59-50).

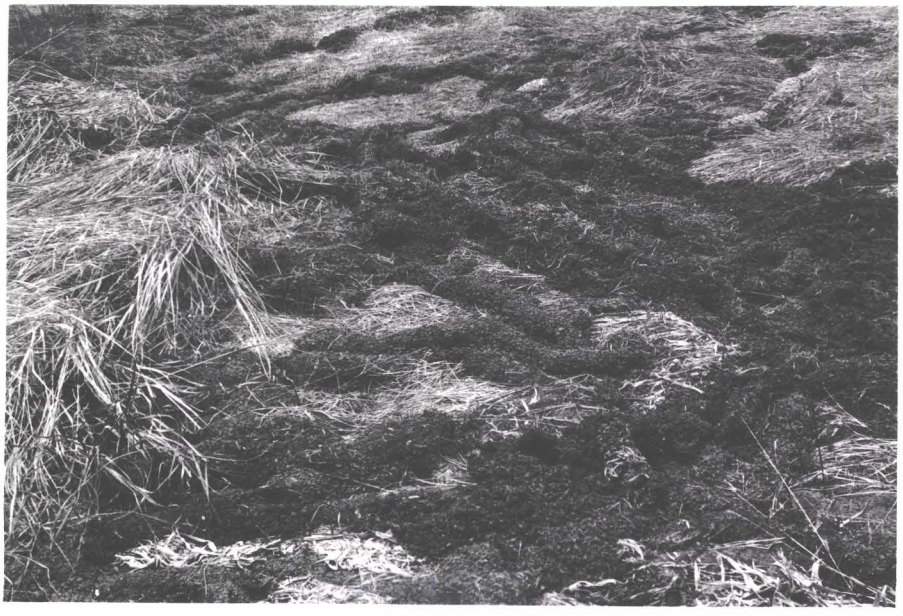


Figure 28.--Casts placed in the snow or in burrows on the soil surface have done some damage to established plants but more damage has been done when seeds or seedlings were covered with soil (59-17).

Pocket gophers apparently eat a wide variety of plants. Food caches observed frequently contained roots, tubers, corms, and bulbs which were usually harvested while burrowing through the soil (figure 29). Observations made in both the spring and fall of 1958 and 1959 were that roots and corms were removed when snow was on the ground by excavating down from the soil surface near each plant (See photos in 1958 Report). Observations made in 1958 and 1959 also indicated that considerable utilization of grasses and forbs took place above the snow. As shown in figure 30, gophers did considerable damage, especially to grasses planted in rows. These animals not only ate the green leaves but also ate part or all of the crowns. In the grass nurseries at Summit Enclosure and at Headquarters the gophers showed preference for orchardgrass, tall oatgrass, and timothy but also damaged the other planted species.

Established grasses, forbs, and shrubs have been damaged or killed when the root system or crowns have been disturbed by burrowing gophers. Damage has occurred both in summer and winter and at relatively low and high elevations. Stands of established crested wheatgrass, Indian ricegrass, and other grasses were severely damaged on a shadscale type near Gunnison, Utah. Primary damage was effected by burrowing beneath the plants and either eating or cutting the root system (figure 31). Damage to many other plants including shadscale also occurred on this site. Shadscale plants were killed by severing the roots as shown in figures 32 and 33. The remainder, or lower fork, of the root systems could not be located by digging, and it is believed that gophers followed and ate these roots.

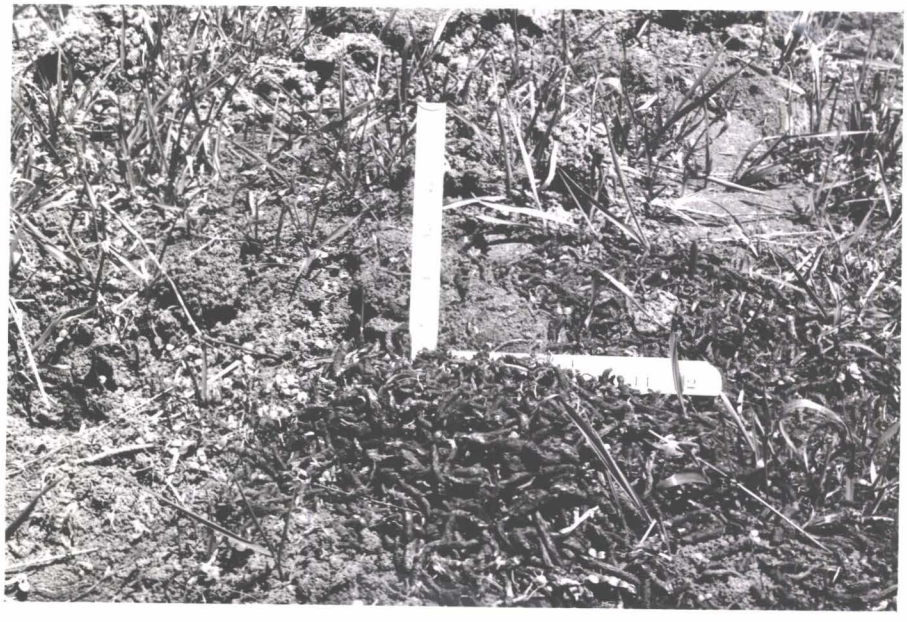
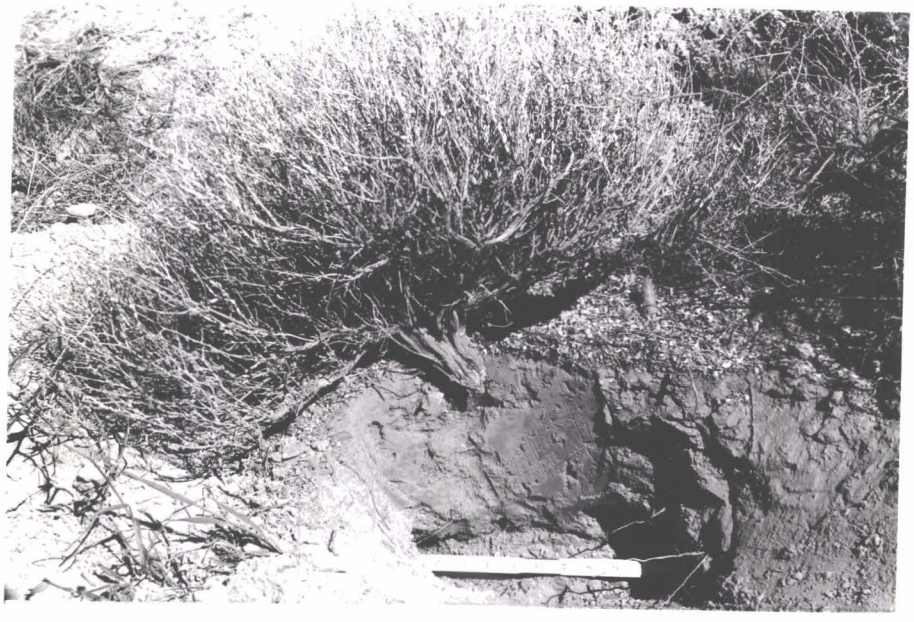
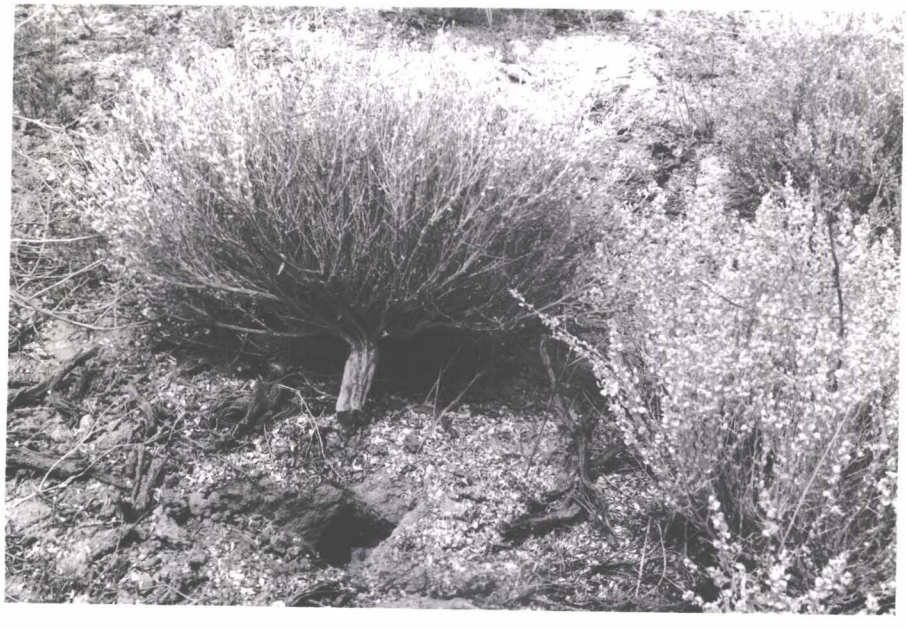


Figure 29.--This food cache, located in the spring of 1959, contained over 3 pints of dandelion roots. Other food caches consisted of bulbs of troutlily, corms of spring beauties, and tubers of starwort (59-60).

Figure 30.--Gophers did considerable damage to planted grasses and forbs in the winter and spring when the area was covered with snow. Gopher trails can be seen along the rows of orchardgrass and casts consisting largely of dead stems, leaves; and waste material can be seen in the foreground (59-16).

Figure 31.--Gopher mounds were abundant in an enclosure in the shadscale type near Gunnison, Utah (59-122).





Figures 32 and 33.--Shadscale plants were killed when gophers severed the roots. Since the lower root system could not be located by digging it is assumed that gophers followed and ate these roots (59-44 and 59-117).

III-B-2. Uniform study for seeding depleted sites on western range

Plans to establish a uniform study were first made at the Range Society Meetings held at Great Falls in January 1957. This study was conducted at six locations, as follows: Bozeman, Montana; Ephraim, Utah; La Grande, Oregon; Logan, Utah; Pullman, Washington; and Reno, Nevada. A general plan of study was made from the composite suggestions by Dr. Keller and the field men located at the locations shown above. A. C. Hull acted as coordinator, and assembled this material into plan form.

Major treatments included 9 seedbed treatments to be applied on the contour and 5 fertilizer treatments applied up and down the slope at right angles to seedbed treatments. The uniform treatments are shown below:

Seedbed treatment

1. Plow fall -- fallow -- seed fall 1 year later
2. Plow nurse crop fall --seed grasses 1 year later
3. Plow fall -- seed following spring
4. Spray spring -- seed spring
5. Spray spring -- seed next fall
6. Plow, seed, and sawdust mulch plus N in fall
7. Plow, contour furrows, seed in fall
8. Plow fall -- transplants fall or spring
9. Plow and seed fall
10. Plow, seed in fall and cover seed with sand

11. Check plot -- no soil preparation or planting

12. Buffer plot -- plow and seed in fall

13. Seed in fall -- spray next spring

Plantings were made on Forest Service land within two enclosures constructed by the Forest Service for this study. The two areas are only about 2 miles apart, but slope and exposure are quite different: (1) Philadelphia Flat -- is located on a wide near level terrace at an elevation of approximately 10,000 feet. This area is frequently snow covered from the first heavy snow in October or November until the air temperature is relatively high the following May or early June when frost danger is low. When dry or unfrozen soil is covered by snow in the fall, the soil may remain at or above freezing throughout the winter. This area is subjected to flooding during rapid snowmelt in the spring. Flooding may also cause a breakdown in the soil structure which in turn may decrease soil aeration, reduce water holding capacity, and favor crusting. (2) Summit Enclosure -- is on a west facing slope of approximately 8 percent at an elevation of 10,200 feet. Snow depth during the winter period on this area is usually less than on Philadelphia Flat due to increased melting in the fall and spring and wind action. Soil may be frozen during the winter. When the soil is bare or snow covering is shallow, alternate freezing and thawing may produce heaving, frost damage, or rapid drying of the surface soil around the seeds. Flooding has been observed but does not appear to be a serious problem on this site.

The first plantings were made on one area at each location according to plan on October 10 - 18, 1957, and spring plantings were made on June 10 - 12, 1958. The first year's results from the planting are included in the Annual Progress Report for 1958

Subsequent plantings at this site were made in the fall of 1958 - spring 1959, and in the fall of 1959. Additional spring plantings will be made after the snow melts in 1960. This report will include the second year results from the 1957 - 1958 plantings and first year's results from the 1958 - 1959 plantings.

Plot areas for the 1958-1959 studies were plowed on August 8 - 10, 1958. Plantings and fertilizer treatments were applied on two replications at each site on October 1 - 3, 1958. Treatments were identical to those applied 1 year earlier.

Species and seed sources used in the first planting were also used in the second planting with two exceptions. On the buffer plot an artic strain of Agropyron spp. was substituted for the chewings fescue. Each nurse crop plot was seeded in 1 foot strips to wheat, Bonneville barley, oats, wheat, and barley instead of the pure plantings of barley used in the fall of 1957. Manchar smooth brome transplants were placed in rows with plants 20 inches apart and with 5 rows per plot, on October 23, 1958.

At the Summit Enclosure the soil was dry until October 19. The first snow fell on November 14 and snow cover was intermittent to December 27 when a heavy snow storm put down 18 inches of new snow. This area remained snow covered until the spring of 1959. The soil was frozen to a depth of 4 to 6 inches on December 1 and to a depth

of approximately 1 foot by December 15. By March 31, 1959 the snow on south and west slopes had settled and melted. Currant bushes on ridges, road markers and road cuts were often visible. By April 13, snow depth was between 9 - 18 inches over the plot area, but did not drop below this depth due to additional snowfall until after May 11.

By May 18 the Summit Enclosure was nearly free of snow and very wet. No sign of grass seedlings could be seen but a few weed seedlings, especially in the valley soil plot were seen. This area was covered with shallow snow on May 19, 21, and 23. The 2-pen thermograph was installed on this site on May 25.

By May 27 the plot area was free of snow as shown in figure 34 and a few grass seeds were starting to germinate but seedlings had not emerged from the soil. This area had been subjected to severe freezing and thawing for a period of over 2 weeks. Most of the plot area showed signs of heaving and other frost action. The surface 1/2 to 1-1/2 inch of native soil was very loose, dry, and crumbly. Most of the planted seeds were found in this loose soil. Underlying native soil was moist but did not bake or crack. The soil in the valley soil plots did not aggregate or mulch on the surface like the native soil but remained wet to the surface. Baking and crusting with deep cracks developed as this soil dried. Dead plants of Polygonum douglasi growing on 1958 valley soil plots were heaved into the air from 2 to 4 inches as shown in figures 35 and 36.

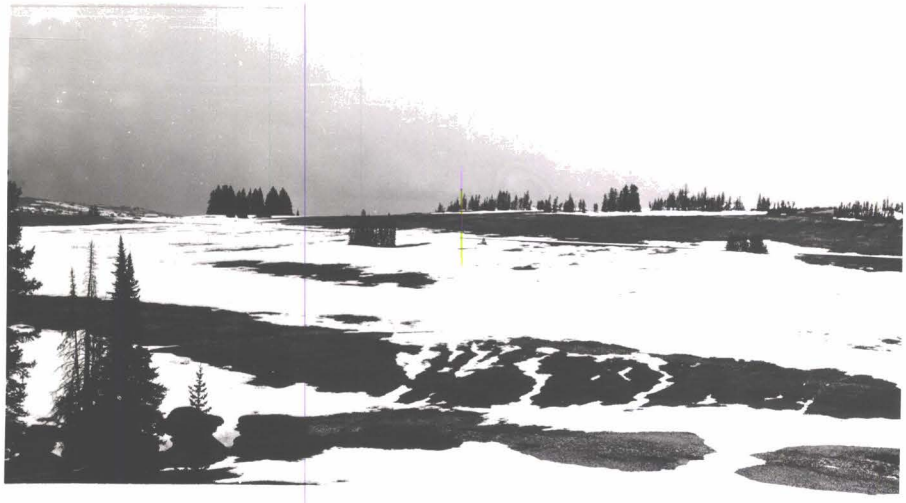
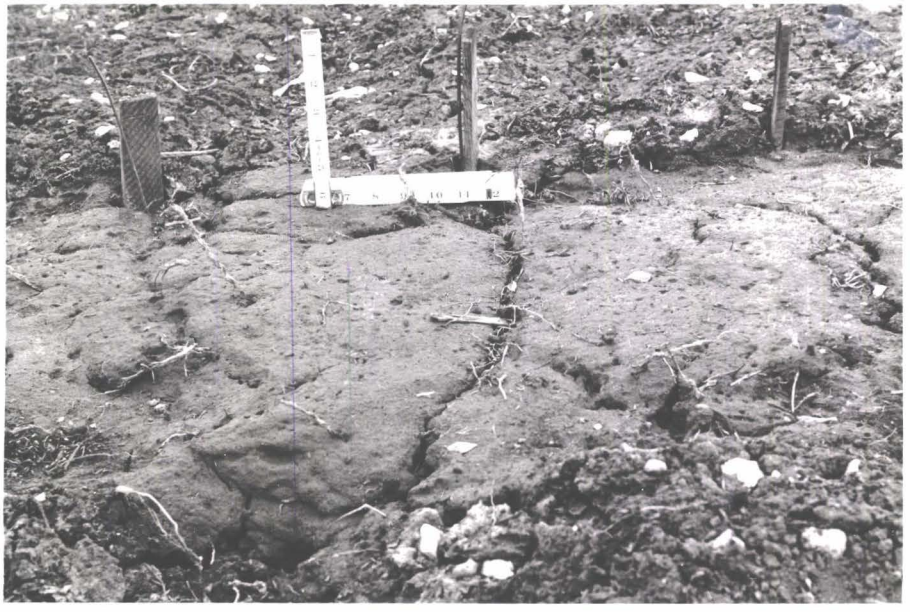
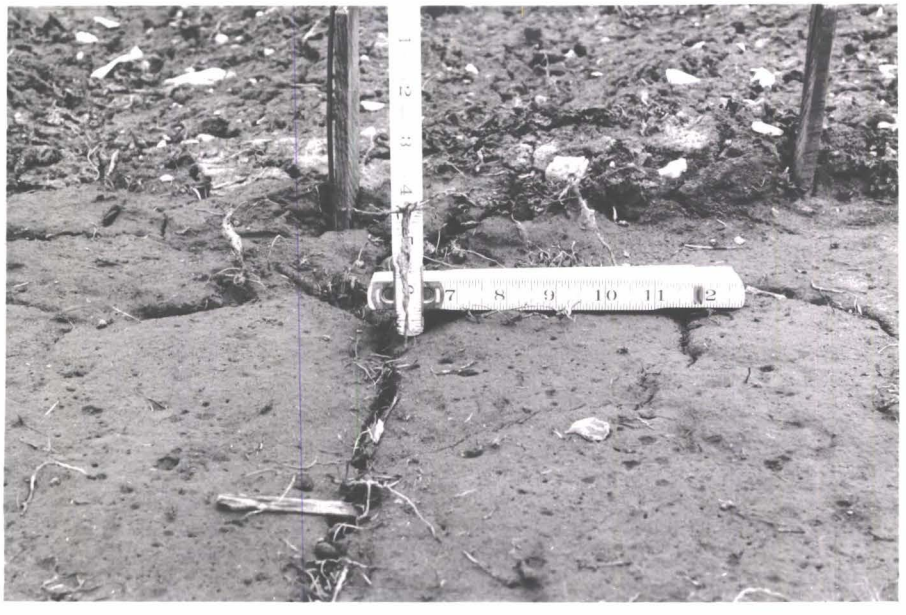


Figure 34.--Snow first left the Summit Enclosure on May 17, 1959 but light intermittent snow storms and low air temperatures retarded seed germination (59-38).





Figures 35 and 36.---Alternate freezing and thawing heaved the top of dead plants of Polygonum douglasi from 2 to 4 inches above the soil on the Valley soil plot (59-42 and 59-43).

On June 1, the spring plantings were made at the Summit Enclosure. On this date alfalfa seedlings were visible at the soil surface. No grass seedlings had emerged but a few of the seeds of slender wheatgrass, intermediate wheatgrass, and smooth brome seeds examined had developed radicles. Most of the grass seeds observed on June 3 were in the loose dry surface soil and had not started to germinate. No gopher damage occurred to this plot during the winter period.

At Philadelphia Flat the soil was very dry up to October 19 and was not frozen on November 13. Snow fell on October 14 and a shallow snow cover remained until about December 20 when snow depth was approximately 20 inches deep, but the soil had already frozen to a depth of 1 to 3 inches. On May 20 the 4-pen thermograph was installed under 25 inches of snow. Snow melted very rapidly during the latter part of May and some bare soil was present on May 30 at 3:00 p.m. and about one-half of the plot was free of snow on June 1. Spring plantings were made on June 3.

Little or no flooding occurred during rapid snowmelt and the soil did not bake or crack. In addition the soil was lightly frozen each night, producing a thin loose soil layer on the soil surface. Gophers invaded the check plots during the winter but did not damage the seeded plots. Numerous seeds had sprouted and the seedlings were just below the soil surface on June 3. Grass seedlings were numerous on the planted plots 1 week after the snow melted from the area (figure 37).

Figure 37.—Philadelphia Flat area 1 week after winter snow melted. Grass seedlings were numerous (59-64).

Seedling counts were made on June 15 and 16 at Philadelphia Flat and on June 16 at the Summit Enclosure (table 9 and table 10). Additional seedling counts were also made about July 8, August 11, and September 21. The number of plants per foot of row during the second growing season were determined on plots planted in the fall of 1957 (table 11). Yield per acre on the established stands were obtained on August 12 at Summit Enclosure and on August 26 at Philadelphia Flat (table 12).

Fertilizers did not appear to improve stand establishment or increase herbage production at either site (tables 13 and 14). Native slender wheatgrass and mountain brome have consistently produced the better seedling stands than the domestic grasses, but these species are relatively short-lived. Fair to good stands of smooth brome, intermediate wheatgrass, pubescent wheatgrass, and an artic Agropyron have been obtained, as shown in table 15. On old nearby studies smooth brome and similar long-lived grasses that spread vegetatively have been superior.

This study has demonstrated that success or failure of a seeding may be determined by one condition on one site and another condition on an adjacent area. In general, treatments that remove the native competition and provide some protection for adapted species have been satisfactory. (1) Native competition has been removed by plowing and cultivating as shown on the summer fallow plot in figure 38. Spraying with 2,4-D did not produce a satisfactory kill when native grasses were abundant in the native vegetation (figure 39). Treatments that have been consistently best at Philadelphia Flat are valley soil, sawdust mulch, and contour furrows. (2) Good seedling stands of native

Table 9 .—Number of plants per foot of row on 10 treatments on two dates during the seedling year at Philadelphia Flat

Species	Fall 1958									Spring 1959	Average
	Drill spray 2/	Drill 2/	Valley soil 2/	Contour furrow 2/	Sawdust + N 2/	Sawdust 2/	Spray drill 1/	Summer fallow 1/	Straw mulch 1/	Drill 2/	
	June 16, 1959										
Slender wheatgrass	4.92	6.57	18.25	5.76	4.91	5.60	2.64	6.18	5.84	1.31	6.20
Tall oatgrass	0.57	1.13	1.25	2.26	1.90	2.50	0.06	0.26	0.24	0.86	1.10
Mountain brome	2.55	4.80	8.00	4.22	4.64	3.25	3.38	6.00	7.00	0.80	4.46
Smooth brome	1.76	4.44	15.00	3.92	5.38	5.70	0.20	2.86	1.60	1.39	4.22
Red fescue	1.10	3.02	25.25	1.84	2.90	4.30	0.22	0.66	3.04	0.31	4.26
Total	10.90	19.96	67.75	18.00	19.73	21.35	6.50	15.96	17.72	4.67	20.25
Average	2.18	3.99	13.55	3.60	3.95	4.27	1.30	3.19	3.54	0.93	4.05
	Sept. 21, 1959										
Slender wheatgrass	3.51	5.76	12.50	5.16	6.31	6.10	2.58	5.90	3.94	1.10	5.29
Tall oatgrass	0.34	1.33	1.50	1.06	1.29	1.60	0.20	0.18	0.02	0.39	0.79
Mountain brome	2.17	5.30	9.50	4.92	4.45	3.90	2.50	5.82	5.68	1.05	4.53
Smooth brome	0.65	4.10	11.50	3.30	3.92	4.00	0.24	1.92	0.86	1.54	3.20
Red fescue	0.29	0.81	12.00	1.07	2.66	4.10	0.04	0.26	0.26	0.23	2.17
Total	6.96	17.30	47.00	15.51	18.63	19.70	5.56	14.08	10.76	4.31	15.98
Average	1.39	3.46	9.40	3.10	3.73	3.94	1.11	2.82	2.15	0.86	3.20

1/ Plants on one replication

2/ Average number of plants on two replications

Table [10] .--Number of plants per foot of row on 10 treatments on two dates during the seedling year at the Summit Enclosure

Species	Fall 1958						Spring 1959				Average
	Drill spray 2/	Drill 2/	Valley soil 2/	Contour furrow 2/	Sawdust + N 2/	Sawdust 2/	Spray drill 1/	Summer fallow 1/	Straw mulch 1/	Drill 2/	
	June 16, 1959										
Slender wheatgrass	0.61	1.55	2.50	2.13	1.52	3.10	0.16	0.52	1.28	0.00	1.34
Tall oatgrass	0.00	0.04	0.00	0.38	0.13	0.25	0.00	0.00	0.14	1.15	0.21
Mountain brome	0.61	2.42	1.50	2.48	2.58	2.75	0.46	1.00	1.08	0.48	1.54
Smooth brome	0.33	1.30	0.50	1.80	1.38	2.80	0.26	0.38	0.80	1.84	1.14
Red fescue	0.07	0.27	0.50	0.42	0.25	0.55	0.08	0.00	0.00	0.28	0.24
Total	1.62	5.58	5.00	7.21	5.86	9.45	0.96	1.90	3.30	3.75	4.47
Average	0.32	1.12	1.00	1.44	1.17	1.89	0.19	0.38	0.66	0.75	0.89
	Sept. 21, 1959										
Slender wheatgrass	0.67	2.05	0.12	1.92	2.30	3.35	0.26	0.92	0.64	1.41	1.36
Tall oatgrass	0.04	0.06	0.00	0.44	0.07	0.45	0.00	0.00	0.02	1.46	0.25
Mountain brome	0.51	2.30	3.50	2.74	2.86	2.95	0.40	1.34	0.80	3.05	2.04
Smooth brome	0.16	1.42	0.25	1.97	1.66	2.65	0.02	0.60	0.26	3.14	1.21
Red fescue	0.01	0.41	0.25	0.17	0.24	0.85	0.00	0.22	0.10	1.06	0.33
Total	1.39	6.24	4.12	7.24	7.13	10.25	0.68	3.08	1.82	10.12	5.19
Average	0.28	1.25	0.82	1.45	1.43	2.05	0.14	0.62	0.36	2.02	1.04

1/ Plants on one replication

2/ Average number of plants on two replications

Table 11 .--Number of plants per foot of row on seven treatments during the second growing season on two dates at Philadelphia Flat and Summit Enclosure

Species	Planted Fall - 1957						Spring-1958	
	Drill spray	Drill	Valley soil	Contour furrow	Sawdust + N	Sawdust	Drill	Average
				Philadelphia Flat - June 16, 1959				
Slender wheatgrass	1.72	7.32	30.00	5.98	15.04	20.90	5.02	12.28
Tall oatgrass	0.02	0.00	9.00	0.00	0.00	0.00	0.50	1.36
Mountain brome	2.22	7.08	54.00	9.28	10.04	13.00	6.04	14.57
Smooth brome	0.36	0.00	21.00	0.00	0.24	0.00	0.72	3.19
Red fescue	0.06	0.00	8.50	0.00	0.00	0.00	0.74	1.33
Total	4.38	14.40	122.50	15.26	25.32	33.90	13.02	32.73
Average	0.87	2.88	24.50	3.05	5.06	6.78	2.60	6.54
				Philadelphia Flat - Aug. 12, 1959				
Slender wheatgrass	1.26	4.58	8.50	2.52	2.70	5.10	2.78	3.92
Tall oatgrass	0.02	0.00	0.00	0.02	0.00	0.00	0.24	0.04
Mountain brome	1.26	2.72	22.00	4.50	3.50	5.60	3.34	6.13
Smooth brome	0.26	0.02	2.00	0.00	0.02	0.00	0.50	0.40
Red fescue	0.00	0.00	4.50	0.00	0.08	0.00	0.20	0.68
Total	2.80	7.32	37.00	7.04	6.30	10.70	7.06	11.17
Average	0.56	1.46	7.40	1.41	1.26	2.14	1.41	2.23
				Summit - June 16, 1959				
Slender wheatgrass	0.14	0.16	0.00	0.66	12.46	7.90	1.24	3.22
Tall oatgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.03
Mountain brome	0.12	0.10	0.00	1.30	3.04	2.30	2.06	1.27
Smooth brome	0.00	0.00	0.00	0.02	0.84	1.90	3.06	0.83
Red fescue	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.02
Total	0.26	0.26	0.00	1.98	16.34	12.10	6.72	5.37
Average	0.05	0.05	0.00	0.40	3.27	2.42	1.34	1.07
				Summit - Aug. 12, 1959				
Slender wheatgrass	0.16	0.06	0.00	0.54	4.56	6.10	1.08	1.79
Tall oatgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01
Mountain brome	0.02	0.04	0.00	0.52	1.08	1.70	2.06	0.77
Smooth brome	0.00	0.04	0.00	0.02	0.38	1.20	2.02	0.52
Red fescue	0.00	0.00	0.00	0.00	0.02	0.00	0.02	0.01
Total	0.18	0.14	0.00	1.08	6.04	9.00	5.22	3.10
Average	0.04	0.03	0.00	0.22	1.21	1.80	1.04	0.62

Table 12 .--Oven dry yield in pounds per acre for planted species during the second growing season and native species at Philadelphia Flat and Summit Enclosure

Species	Fall - 1957						Spring - 1958			Buffer F-57	
	Drill spray	Drill	Valley soil	Contour furrows	Sawdust + N	Sawdust	Drill	Trans plants	Check	Species 9/	Yield
Phil. Flat - Aug. 26, 1959											
Slender wheatgrass	63.0	499.2	1008.0	222.9	505.3	693.1	139.0	-	-	Agin^2	3.0
Tall oatgrass	1.0	0.0	0.0	1.0	0.0	0.0	12.0	-	-	Agtr^2	6.0
Mountain brome	63.0	710.4	0.0	652.6	1310.4	778.6	167.0	-	-	Alpr	2.0
Smooth brome	13.0	0.0	1680.0	0.0	1.0	0.0	25.0	467.0	-	Dagl	2.0
Red fescue	0.0	0.0	1.0	0.0	4.0	0.0	10.0	-	-	Feruc	0.0
Other species	765.2	545.0	-	557.0	575.0	357.2	706.7	545.0	1638.9		844.1
Summit - Aug. 12, 1959											
Slender wheatgrass	8.0	3.0	0.0	27.0	1168.9	814.3	54.0	-	-	Agin^2	72.0
Tall oatgrass	0.0	0.0	0.0	0.0	0.0	0.0	2.0	-	-	Agtr^2	36.0
Mountain brome	1.0	2.0	0.0	26.0	146.4	120.1	103.0	-	-	Alpr	0.0
Smooth brome	0.0	4.0	0.0	2.0	38.0	120.0	202.0	114.4	-	Dagl	1.0
Red fescue	0.0	0.0	0.0	0.0	0.0	0.0	1.0	-	-	Feruc	0.0
Other species	687.0	630.3	0.0	661.5	811.4	811.4	913.2	630.3	506.9		906.1
	2/	7/		1/	3/		6/	4/	5/		8/

1/ - 85% Taof, 5% Acla, 5% Ardi, 5% other
2/ - 30% Stle, 15% Agtr, 5% Acla, 5% Brca, 40% Taof, 5% other
3/ - 98% Taof, 1% Ardi, 1% other
4/ - 96% Taof, 1% Popu, 2% Acla, 1% other
5/ - 55% Taof, 10% Agtr, 10% Stle, 10% Acla, 5% Ardi, 5% Popu, 5% other
6/ - 90% Taof, 5% Acla, 5% other
7/ - 96% Taof, 1% Popu, 2% Acla, 1% other
8/ - 85% Taof, 5% Acla, 5% Ardi, 5% other
9/ - Agin^2 = Agropyron intermedium, Agtr^2 = A. spp, Alpr = Alopecurus pratensis, Dagl = Dactylis glomerata, and Feruc = Festuca rubra.

Table 13 .--Number of plants per foot of row by fertilizer treatments on various seeding treatments on two dates during the seedling year on Philadelphia Flat

Site 1	Fall 1958									Spring 1959	
	Drill spray 2/	Drill 2/	Valley soil 2/	Contour furrow 2/	Sawdust + N 2/	Sawdust 2/	Spray drill 1/	Summer fallow 1/	Straw mulch 1/	Drill 2/	Average 3/
Fertilizer	June 16, 1959										
Check - None	2.08	3.79	13.55	3.62	3.70	4.27	1.48	3.68	4.84	0.88	3.01
Nitrogen	2.56	4.16	-	3.39	3.82	-	1.68	2.52	3.46	1.06	2.83
Phosphorus	1.90	3.77	-	3.65	4.08	-	1.18	3.80	3.82	0.82	2.88
N + P	2.22	4.23	-	3.43	4.15	-	1.12	3.26	2.56	1.24	2.78
Complete	2.14	4.01	-	3.91	3.98	-	1.04	2.70	3.04	0.67	2.69
Total	10.90	19.96	-	18.00	19.73	-	6.50	15.96	17.72	4.67	14.19
Average	2.18	3.99	-	3.60	3.95	-	1.30	3.19	3.54	0.93	2.84
	Sept 21, 1959										
Check - None	1.33	3.41	9.40	3.05	3.28	3.94	1.14	3.24	2.58	0.93	2.37
Nitrogen	1.64	3.38	-	3.25	3.51	-	1.00	2.74	2.22	0.96	2.34
Phosphorus	1.04	3.61	-	2.84	4.44	-	0.96	3.42	2.20	0.75	2.41
N + P	1.61	3.56	-	3.19	3.73	-	1.36	2.92	1.76	1.10	2.40
Complete	1.34	3.34	-	3.18	3.67	-	1.10	1.76	2.00	0.57	2.12
Total	6.96	17.30	-	15.51	18.63	-	5.56	14.08	10.76	4.31	11.64
Average	1.39	3.46	-	3.10	3.73	-	1.11	2.82	2.15	0.86	2.33

1/ Plants on one replication

2/ Average number of plants on two replications

3/ Valley soil and sawdust not included in this average

Table 14 .—Number of plants per foot of row by fertilizer treatments on various seeding treatments on two dates during the seedling year at the Summit Enclosure

Site I	Fall 1958									Spring 1959	
	Drill spray 2/	Drill 2/	Valley soil 2/	Contour furrow 2/	Sawdust + N 2/	Sawdust 2/	Spray drill 1/	Summer fallow 1/	Straw mulch 1/	Drill 2/	Average 3/
	June 16 and 19										
Check - None	0.33	0.99	1.00	1.34	1.05	1.89	0.20	0.34	0.42	0.77	0.68
Nitrogen	0.25	0.86	-	0.90	0.83	-	0.14	0.46	0.80	0.64	0.61
Phosphorus	0.31	1.19	-	1.32	1.40	-	0.28	0.40	0.62	0.74	0.78
N + P	0.27	1.39	-	1.36	1.40	-	0.14	0.38	0.66	0.61	0.78
Complete	0.46	1.15	-	2.29	1.18	-	0.20	0.32	0.80	0.99	0.92
Total	1.62	5.58	-	7.21	5.86	-	0.96	1.90	3.30	3.75	3.77
Average	0.32	1.12	-	1.44	1.17	-	0.19	0.38	0.66	0.75	0.75
	September 21, 1959										
Check - None	0.24	1.13	0.82	1.39	1.47	2.05	0.22	0.44	0.20	2.24	0.92
Nitrogen	0.27	0.88	-	1.07	0.98	-	0.12	0.68	0.20	1.50	0.71
Phosphorus	0.28	1.41	-	1.34	1.69	-	0.00	0.66	0.34	2.18	0.99
N + P	0.24	1.55	-	1.53	1.63	-	0.12	0.66	0.56	2.29	1.07
Complete	0.36	1.27	-	1.91	1.36	-	0.22	0.64	0.58	1.91	1.02
Total	1.39	6.24	-	7.24	7.13	-	0.68	3.08	1.82	10.12	4.71
Average	0.28	1.25	-	1.45	1.43	-	0.14	0.62	0.36	2.02	0.94

1/ Plants on one replication

2/ Average number of plants on two replications

3/ Valley soil and sawdust not included in this average

Table 15 .--Number of plants by species and by fertility treatment per foot of row on the Buffer Plot at Philadelphia Flat and Summit Enclosure on two dates during the seedling year

	Philadelphia Flat				Summit Enclosure			
	Site II		Site III		Site II		Site III	
Species	June 16	Sept 21	June 16	Sept 21	June 16	Sept 21	June 16	Sept 21
Meadow foxtail	1.44	1.22	2.56	0.96	0.10	0.28	0.26	0.16
Orchardgrass	5.90	4.58	7.62	3.86	1.80	1.96	1.00	0.88
Agropyron spp.	2.74	1.82	3.90	2.88	3.08	2.88	2.08	2.14
Intermediate wheatgrass	3.28	3.70	4.80	3.30	2.36	2.28	2.46	2.28
Stiffhair wheatgrass	2.92	2.72	4.78	3.20	1.90	1.72	3.24	2.76
Total	16.28	14.04	23.66	14.20	9.24	9.12	9.04	8.22
Average	3.26	2.81	4.73	2.84	1.85	1.82	1.81	1.64
Fertilizers								
Check - none	3.00	2.64	4.46	2.50	2.44	2.04	1.56	1.22
Nitrogen	3.68	3.16	4.62	3.10	1.58	1.56	1.30	1.32
Phosphorus	3.54	3.12	4.82	2.92	2.30	2.18	1.76	1.94
N + P	2.96	2.48	4.96	2.80	1.16	1.24	1.72	1.50
Complete	3.10	2.64	4.80	2.88	1.76	2.10	2.70	2.24
Total	16.28	14.04	23.66	14.20	9.24	9.12	9.04	8.22
Average	3.26	2.81	4.73	2.84	1.85	1.82	1.81	1.64

Figure 38.--Good seedling stands of mountain brome and slender wheatgrass were produced when the native vegetation was removed by plowing followed by summer fallow (59-78).

Figure 39.--When grass plants were an important part of the competing native vegetation spraying with 2,4-D did not produce a satisfactory kill (59-101).

mountain brome and native slender wheatgrass have also been obtained on the fall drill. Differences in plant numbers between the fall drill, contour furrow and sawdust mulch plots were small but these treatments were superior to fall drill-spray in spring treatments and spring plant treatments (figures 40, 41, and 42).

The treatment that has been consistently best at Summit Enclosure is sawdust mulch and the spring drilling has been next best. Plant numbers were low on other treatments at the Summit Enclosure.

Figure 40.--Good seedling stands of all planted species were obtained on the small valley soil plot in the immediate foreground, but only good stands of native species were obtained on the adjoining fall drill plot (59-99).

Figures 41 and 42.--Good stands of native slender wheatgrass and native mountain brome were obtained in the sawdust mulch and contour furrow plots (59-80 and 59-81).

III-B-3. Stand establishment and free-water in the snow on the soil surface

A water table, in the snow, on top of the soil is formed when the water produced on an area from rapid snowmelt plus supplemental drainage into the area exceeds the percolation rate of water into the soil plus overland drainage from this area. Traps set out in the fall of 1956, 1957, and 1958 and actual measurements on selected areas during rapid snowmelt in the spring of 1957, 1958, and 1959 showed that free-water under snow existed on some shallow, heavy textured soils that drain rapidly when the soil is snow free.

In the spring of 1957 all cans placed at levels of 1, 2, or 3 inches on shallow, heavy textured soil with slopes less than 5 percent were filled with water. In addition, some cans placed with the openings at 1 inch above a heavy soil on slopes of approximately 10 to 15 percent were filled with water.

Free-water traps put out in the fall of 1957 and inspected in the spring of 1958 indicated that, in general, depth of free-water had been less than in the spring of 1957. This may have been due to less moisture in the snowpack, snow melting 20 days earlier, or the period rate of melt was slower. In general, only the cans placed at 1/2 and 1 inch above the soil surface were filled with water, but cans on slopes of more than 5 percent were not filled with water. Maximum flooding occurred on June 6 when a large portion of Philadelphia Flat was covered with water. Depth of water on about 60 acres ranged from 1/2 inch on the higher areas to over 15 inches in many of the drainages.

In the spring of 1959 the snow melted a few days earlier than in 1958. Only a few cans at the 1 inch height above the soil were filled with water and duration of flooding was shorter than in 1957 or 1958. This was probably due to the relatively low temperatures and slow melting of the snow after the snow depth had been reduced to 27 inches. After the snow depth decreased to about 36 inches shrubs and stiff stalks of forbs were exposed. Melting of snow around these exposed stems and stalks was faster than on adjacent areas as shown in figures 43 and 44.

Row plantings of smooth brome were made adjacent to the free-water traps each fall so correlation of seedling stands on these areas could be made with depth of water. These plantings show that flooding may result in damage or death of seeds, seedlings, and some established perennial plants. Flooding may also cause a breakdown in soil structure which in turn will reduce water holding and aeration of the soil and favor soil crusting. Furrows 20 to 100 feet long and 4 inches deep were made with a hand cultivator. Seeds were planted at a depth of 3/4 inch in the bottom of each furrow with a Planet Jr. Seeding rate with the Planet Jr. was set for 10 pounds per acre when rows were spaced 1 foot apart.

Seedling stands of smooth brome were very poor in the spring of 1957 and poor to fair in the spring of 1958. In the spring of 1959 when little flooding occurred good stands of seedlings were produced on most areas.

Figures 43 and 44.—Snow melted faster around exposed stems and other dark colored objects than on adjacent areas. Hollow spaces were often developed at the base of plants or over dark colored objects that were below the surface of the snow (59-28 and 59-29).

Additional free-water traps and row plantings were placed at selected locations in the fall of 1959 to obtain additional information on depth of free-water under the snow during rapid snowmelt and the fate of seeds subjected to conditions existing in the winter and spring of 1960.